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ENGINES OF WAR:

OR,

HISTORICAL AND EXPERIMENTAL

OBSERVATIONS

ON

ANCIENT AND MODERN

WARLIKE MACHINES AND IMPLEMENTS,

INCLUDING THE MANUFACTURE OF

GUNS, GUNPOWDER, AND SWORDS

WITH REMARKS ON

BRONZE, IRON, &c.

HENRY W[illegible] F.R.A.S.

HONORARY [illegible] OF THE INSTITUTION,

[illegible]

LONDON: [illegible] LONGMANS.

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DEDICATED,

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THE RIGHT HONOURABLE

SIR HUSSEY VIVIAN, BART. M.P.

MASTER GENERAL OF THE ORDNANCE,

ETC. ETC ETC.

SIR,

The honour you have conferred on this first effort cannot be otherwise than gratifying to my feelings, by evincing your confidence in the character of a work, at the head of which you have allowed me to place your name. At the same time my satisfaction is not unalloyed by fear, lest the expectation raised by your patronage should be disappointed. It

cannot be expected that I should be able to communicate much, if any, information on such subjects, to one so well acquainted as yourself with all the duties of your high and responsible station; particularly as it is universally acknowledged, that at no former period has greater energy been infused into your department, nor greater courtesy shown to those who have occasion to avail themselves of your kindness; of which no one can feel more truly sensible than,

Sir,

PREFACE.

SOME years ago the Author was induced by his friend, Professor Faraday, to give a lecture at the Royal Institution, "on the Warlike Machines of the Ancients:" this led to many others in different places, and considerable information was collected in a popular and condensed form, which has been found interesting to persons generally, as well as to those of the naval and military professions, for whom such subjects might appear to be more especially suited.

The writer is not aware of the existence of any small work embracing so wide a field as that to which he has devoted his attention, in consequence of the opportunities of peculiar information afforded by his professional pursuits: he is, therefore, led to hope that this volume may form a valuable class-book for young naval and military students, as well as an useful work of reference to officers generally.

It is presumed that a sufficient apology for

the style of the author will be found in his object, which is, to convey the greatest amount of information in the fewest words possible.

The historical part is compiled from the most authentic sources; and will save the time of those who desire to obtain some knowledge of these subjects without much research; and for those who wish for more extended information ample opportunity will be afforded by references to numerous authors.

In the theoretical and practical portions it is anticipated that some original matter will be found, and that each reader may discover at least one fact with which he was previously unacquainted: how far this has been accomplished the public must determine.

Pall Mall, Feb. 1. 1841.

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ENGINES OF WAR,

ETC.

PART I.

ON THE WARLIKE MACHINES OF THE ANCIENTS, ETC.

THERE is no subject more intimately connected with the history of the world, from the remotest period, than the history of arms, the fate of nations having always depended either on the superiority of the arms employed, or on the superior discipline and dexterity of those who used them, wholly independent of the numbers by which they were opposed.

The examples recorded are innumerable: amongst the most striking may be instanced the almost invariable success of the Roman infantry, in all their charges, from their peculiar method of using the sword and shield: the former, being about two feet long, was used for thrusting only, as we use the bayonet; and the latter, having a boss with a sharp spike in the centre,

could inflict a mortal wound, while at the same time it defended the bearer.

The conquest of this country by the Romans was effected entirely by their great superiority over our ancestors in discipline and arms; and the most memorable battle ever fought, considering the multitude slaughtered on the one side compared with the few who were engaged on the other, was that wherein 100,000 Britons, headed by Boadicea, were totally defeated, and 80,000 slain, by 10,000 Romans commanded by Pauline, with a loss on their part of only 400 killed, and an equal number wounded.[1]

These preliminary observations are merely introduced to prove the importance of improvements in arms to every country.

Fenelon justly observes, that, "To be always prepared for war, is the surest way to avoid it."[2]

A mere enumeration of all the known machines or instruments that have been contrived by the ingenuity of man for the destruction of his fellow-creatures, would far exceed my prescribed limits: necessity, undoubtedly, led to the invention of many of them for the purposes of the chace, which were afterwards employed in warfare.

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[1] Tacitus, Hist. Rapin, Hist. d'Angleterre, tom. i. p. 45.

[2] Telemachus, p. 216. 4to.

I shall not pretend to determine the precise period when men first began to quarrel, as in those days we may safely conclude that the only engines were their own muscular powers, and the only missiles, stones.

Every means, therefore, by which stones could be thrown with greater force than by the hand alone, would naturally be resorted to: accordingly, we find the sling ranks among the first of ancient offensive weapons.

Numerous examples are recorded in Scripture; to mention only that of David and Goliath is sufficient.[1]

Pliny[2] ascribes the invention of slings to the Phœnicians, but Vegetius[3] attributes it to the inhabitants of the Balearic islands (now called Majorca and Minorca), who were famous in antiquity for using them. Hence Ovid[4],

——— "Balearica plumbum
Funda jacit; volat illud et incandescit eundo;"

translated by Garth[5],

"So the cold bullet that with fury slung
From Balearic engines mounts on high."

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[1] 1 Samuel, xvii. 40. 49. [2] Lib. lxvi. c. 5.
[3] De Re Militari. Parisiis, 1553, 4to.
[4] Met. lib. ii. v. 729. [5] Garth's Ovid, vi. p. 70.

And Virgil [1],—

———"figere damas,
Stuppea torquentem Balearis verbera fundæ:"

thus rendered by Dryden [2],—

"With Balearic slings, or Gnossian bow,
To persecute from far the flying doe."

Florus and Strabo say, "those people bore three kinds of slings, some longer and others shorter, to be used as their enemies were nearer or more remote." Diodorus Siculus adds, that "the first served them for a head-band, the second for a girdle, and the third they always carried in their hands: in fight, they threw large stones with such violence, that they seemed to be projected from some machine, so that no helmet or armour could resist the stroke; and with such exactness as rarely to miss their aim, being constantly exercised from their infancy, their mothers not allowing them to have any food until they struck it down from the top of a pole with stones thrown from their slings."[3]

It was likewise common in Greece. The

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[1] Georgicon, lib. i. v. 308.
[2] Dryden's Virgil, Georgics, book i. v. 415.
[3] Vegetius, De Re Militari, lib. i. c. 16.

Acarnanians[1] are said by some to have invented it, while others give the honour to the Ætolians[2]; but none of them managed it so skilfully as the Achaians[3], who inhabited Ægium, Dyma, and Patræ: they are reported to have excelled the Balearians.

This weapon was principally used by the light armed soldiers. Cyrus considered it unbecoming an officer[4]; and Alexander wishing to render his enemies as contemptible as possible to his own soldiers, calls them "a disorderly rabble, designed for no other purpose than to cast stones out of a sling."[5] Arrows, stones, and leaden plummets, were thrown from them, some of which weighed no less than an Attic pound.[6]

The manner of slinging was by whirling it twice or thrice about the head before they discharged the bullet: thus Mezentius in Virgil[7],—

"Thrice round his head the loaded sling he whirled:"

but Vegetius commends those as the greatest artists who cast it out with one turn about the head. Seneca reports that its motion was so vehement, that the leaden plummets were frequently melted.

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[1] Pollux, lib. i. c. 10.
[2] Strabo.
[3] Livius, lib. xxxviii.
[4] Suidas.
[5] Xenophon, Cyrop. i. 7.
[6] Curtius.
[7] Æneid, lib. ix. 587.

It is curious to remark the derivation of words: the Latin for our English word farm is *fundus*, which word originally signified "a stone's throw of land," and is derived from *funda* a sling, as we find in this verse, —

"Fundum Varro vocat, quà possis mittere funda;"

thus defining a farm to have been formerly as much land as could be included within the range of a stone thrown from a sling.

The stones thrown by Homer's heroes without slings, were such as the united strength of several men of the present day would be unable to lift. Ajax and Hector encountered each other with similar weapons, —

"A stone so big you might a mill-stone call;"

and Minerva attacked the God of War with a stone which, in former ages, had been used as a land-mark. These are, however, poetical fictions; but we learn from them, that stones were considered formidable destructive weapons.

The materials of which slings were composed were either flax, hair, or leather, woven into bands or cut into thongs, broad in the centre to receive the load, and tapering off to the extremities.[1] They were sometimes at-

[1] Archæologia.

tached to sticks, to increase their power; and the Greeks, as well as Romans, projected darts and javelins by the assistance of a sling or strap, girt round their middle, whence Seneca in his Hippolitus says,—

> " The strap with your forefinger draw,
> Then shoot with all your strength."

Froissart[1] gives an instance in which slings were used by the people of Brittany in behalf of the English, in a battle fought in that province in the reign of Philip de Valois; and, according to this author, they were also used in naval combat.

D'Aubigné records the fact, that slings were used at the siege of Sancerre in 1572 by the Huguenots, in order to save their powder; and hence, he says, they were called " Sancerre harquebusses." This is probably the last instance of their use in European warfare; although it is stated by Sir Robert Wilson, that at the battle of Alexandria the French and English threw stones at each other, during a temporary want of ammunition, with such effect that a serjeant of the 28th regiment was killed, and several of the men were wounded.[2] Slings

[1] Chron. v. i. c. 85.

[2] History of the British Expedition to Egypt.

are still used by the children in India to drive birds from the corn-fields.

Before I quit this portion of my subject, it may be proper to notice the peculiar method of throwing the javelin adopted by the aborigines of Australia, which does not appear to have been practised in any other part of the world. The javelin is very long, and has a cavity at one end into which the hook of the throwing stick is inserted, which stick is a flattened piece of wood about two feet long, with a small hook firmly bound at one end, by means of which the javelin can be thrown to a much greater distance than in any other way, forming, in fact, an inflexible sling.

The power of these instruments depends on the greater velocity given to the stone in consequence of its increased distance from the centre of motion, the shoulder joint; therefore, the longer the sling can be conveniently managed, the greater will be the effect, the force being estimated by multiplying the weight by the velocity: but of this I shall give a few examples when speaking of the battering-ram and the balista, the latter engine bearing the same relation to the sling, as cannon do to muskets and other small fire-arms.

I now proceed to the Bow, which may be traced to the earliest times in the annals of every

country. The Hiddekel, one of the four rivers named in Genesis, ii. 14., which is now called the Tigris, and was named Teer by the ancient Persians, signifies in the Persian language an arrow; probably so named from the rapidity of its course, by which it appears, either that archery was known even at that remote period (B. C. 4004), or that arrows were named after that river from their rapid flight; but the former of these suppositions is the more probable.

The ancients ascribed the invention of the bow to Apollo, and the primitive inhabitants of Crete are said to have been the first mortals to whom it was communicated: hence the Cretan bows were famous, and preferred even in later ages by the Greeks to all others.[1]

Perses the son of Perseus has been honoured with the invention, while some ascribe it to Scythes the son of Jupiter, and progenitor of the Scythians, who were not only excellent archers, but by many reputed the first masters of archery.[2] These tales serve to prove that its antiquity must be referred to the remotest periods.

The earliest instance in the Old Testament,

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[1] Diodorus Siculus and Isidorus. Potter's Archæologia.

[2] Pliny. Pollux.

where the use of the bow is implied, occurs in Genesis, xxi. 20., where it is said of Ishmael, "and God was with the lad, and he grew and dwelt in the wilderness, and became an archer:" the connection of this with the fourth preceding verse implies an earlier practice with the bow than can be adduced by any profane historian, being 1892 years before Christ, or nearly 4000 years ago.

"The Saracens, who were of the posterity of Ishmael, never set their hands to the plough, but got their living for the most part by the bow, supporting themselves on wild flesh and venison, and such wildfowl as the wilderness afforded, with herbs and milk."[1]

Many passages in Scripture attest the continued use of the bow: the overthrow of Saul was particularly owing to the Philistine archers; and David "bade them teach the children of Judah the use of the bow."[2] The practice of it at this time appears to have been so general, that it was not unfrequently employed as a figure of speech.

Israel when blessing his sons says of Joseph, "the archers have sorely grieved him, and shot at him, and hated him; but his bow abode in

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[1] Bishop Patrick, notes to Mant's Bible, Gen. xxi. 20.

[2] 2 Sam. i. 18.

strength, and the arms of his hands were made strong by the hands of the mighty God of Jacob."[1]

The companies that came to David at Ziklag "were armed with bows, and could use the right hand and the left in hurling stones and shooting arrows out of a bow."[2]

The Grecians derived their knowledge of the bow from the Scythians, who taught their ancient nobility the use of it, which in those days passed for a princely education. Thus Hercules was taught by Teutarus[3], a Scythian swain, from whom he received a bow and arrows of Scythian make: whence Lycophron speaking of Hercules' arrows says,

"With arrows which he had from Teutarus."

The Mæotian or Scythian bow was distinguished from the Grecian bow by the singular incurvation of its shape, which was so great as to form a semicircle.[4]

The Grecian bows were usually made of

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[1] Gen. xlix. 23, 24. [2] 1 Chron. xii 2.

[3] Theocritus changed his tutor's name into Eurytus, also of Scythian original. Potter's Antiquities of Greece, vol. ii. p. 41.

[4] Ammianus Marcellinus, lib. xx.

wood, though more anciently, like the Scythian, of horn; as we read of Pandarus in Homer,—

"Straight he pulls out a handsome polished bow,
Once it a wanton he-goat's horn did grow." [1]

And Lycophron speaks thus of Apollo,—

"In battles bent his horn."

The strings were made either of horses' hair, or of hides cut into small thongs: thus Homer,—

"He drew the arrow by the leathern string."

And Accius says,—

"Drawing the arrow with the horses' hair."

The arrows consisted of light wood or reeds, and an iron head, commonly armed with barbs; occasionally they were dipped in poison, for which piece of inhuman skill Virgil's Amycus was famous:—

"Fam'd for his skill, and for his wonderous art,
In giving double force to any dart
Or arrow with his poison." [2]

But this practice was rarely adopted or understood in Greece, being more frequent in barbar-

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[1] Iliad, Δ, v. 105. Archæologia.
[2] Æneid, lib. ix. 772. (Thebaid, lib. ix. Statius.)

ous nations. They were winged with feathers, and carried in a quiver, as in modern times.

In drawing the bow, the primitive Grecians did not pull back the hand towards the right ear, according to the fashion of the ancient Persians[1], and of the modern ages; but, placing the bow directly before them, returned their hand on their right breast [2], which was the custom of the Amazonian women, who are reported to have cut off their right breast, lest it should be any impediment to them in shooting: on which account their name is commonly thought to be derived from the privative particle α, and μαζὸς, a breast; that is, from their want of a breast. Homer speaks thus of Pandarus, —

> "Up to the head the mortal shaft he drew,
> The bowstring touched his breast."

Some of the Persian, Turkish, and Tartar bows resemble the ancient Scythian in form, which is that usually represented by artists, and may be called the classical bow. The construction of them is very curious, and it requires considerable strength and dexterity to string them. They are composed of five or seven

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[1] Procopius, de Bell. Persic. lib. i.
[2] Eustathius. Iliad, Δ, v. 344.

pieces of wood, merely tongued together as a foundation or frame, over which the sinews or entrails of the wild goat are laid, in a moist state, longitudinally, and then slips of buffalo's horn are placed over the broadest parts, the whole being firmly bound together with annular ligaments of the sinews, and glued; they are then covered with tinfoil, painted, and varnished; the elasticity depending on the sinewy fibre. These bows, being short, are peculiarly adapted to horsemen, and are strung by placing one end against the pommel of the saddle, and passing the right leg over it; then, having the string previously attached to one end, it is drawn over with the sword-hand, and the loop slipped into the nock: the bow being strung, the leg is immediately withdrawn. Although very strong, these bows do not possess the lively action of the English long-bow, and they require to be pulled very straight, or they are liable to turn round, and unstring themselves.

It is singular that bows of a similar form, made of wood, should have been found among the Esquimaux Indians. The origin of this peculiar form may be traced from nature: the ancient ones being wholly made of horn, were probably merely the horns of the buffalo, reduced in thickness and inserted into a piece of wood to form the centre or handle, which at once gives the

Scythian bow unstrung; and by reversing the curvature in stringing, as in the Oriental bows, the classical form is obtained.

The Laplanders, who subsist almost entirely by hunting, form their bows of two pieces of tough wood, united together with a very strong glue made from the scales of perch, and these pieces never separate. This method has been adopted in England, and bows thus formed possess much greater force and elasticity than can be obtained from one piece of wood only. In England, the use of the bow was once carried to a degree of perfection, that has never been rivalled.[1] Our ancestors used it in peace for their amusement, and in war for the destruction of their enemies. The Anglo-Saxons and the Danes were well acquainted with it from a very early period, as the Scandinavian Scalds[2] when praising the heroes of their country enumerate among their acquirements a superiority of skill in handling the bow. Amongst them, however, it appears to have been only employed for obtaining food, or for pastime; and we are, perhaps, indebted to the Norman Conquest for its introduction as a military weapon, although the Normans at the battle of Hastings are said to have used the arbalest or cross-bow, as well as the long-bow.

[1] Grose, Hist. Eng. Army, vol. i. p. 140.

[2] Celebrated bards, or poets.

The exact time when shooting with the long-bow began in England is unsettled: our chroniclers do not mention archery till the death of Richard I. in 1199, who was killed by an arrow, said to have been shot from a cross-bow at the castle of Chaluz. Under Edward III. the glory of the English long-bow was at its zenith. Previous to the battle of Cressy in 1346, a shower of rain so slackened the strings of the Genoese cross-bows, that they became unserviceable, while the English were still capable of annoying the enemy with success. This victory, and that of Poictiers ten years afterwards, was chiefly ascribed to the English archers. At the decisive battle of Homildon Hill against the Scots in 1402, the earl of Douglas, whose armour was of the most perfect temper, was wounded in five places, and he found to his cost that the English arrows were so sharp and discharged with such force, that no armour could repel them: the English men-at-arms, knights, and squires, never drew the sword, or couched the lance, the whole affair being decided by the archers: and the victory of Agincourt (1417) was entirely owing to the skill of the archers.[1]

Notwithstanding the great advantages that had evidently accrued to the English from the use of

[1] Grose, Hist. Eng. Army. Rymer. Fordun.

the long-bow, the French were still attached to the arbalest; and Henry V., as duke of Normandy, confirmed the charters and privileges of the *balistarii*, who had been long established at Rouen.

Under Edward IV. every Englishman and Irishman dwelling in England was required by royal ordinance to have a bow of his own height, made of yew, wych, hazel, ash, or auburne, according to his strength; and the inhabitants of every township were required to practise archery under certain penalties. The arrows were directed to be the length of a man's arm, or half the length of the bow.

Even when the use of what we now call artillery gained ground, the bow and arrow were by no means neglected. By stats. 19 Hen. VII. and 6 & 25 Hen. VIII. the use of the cross-bow was entirely forbidden; and by the last statute a penalty of 10*l.* was inflicted on every one in whose house a cross-bow might be found. Numerous statutes were passed to encourage archery in this reign as well as under Elizabeth, James, and Charles I.; but the last time the legislature interfered for the protection of archery was in 1633, when Charles I. issued a commission for preventing the fields near London being so enclosed, "as to interrupt the necessary and profitable exercise of shooting."

Sir William Davenant[1], in a mock poem entitled "The Long Vacation in London," describes the attorneys and proctors as making matches in Finsbury Fields, —

> "With loynes in canvas bow-case tied,
> Where arrows stick with mickle pride,
> Like ghosts of Adam Bell and Clymme,
> Sol sets for fear they'll shoot at him."

Adam Bell and Clymme were noted outlaws, as famous in the northern, as Robin Hood and Little John were in the midland counties.

However celebrated the English may have been collectively as archers, we have few instances of individual dexterity equal to that recorded of William Tell's shooting an apple from his son's head[2], which popular fiction we have been accustomed from our childhood to consider as an historical fact; and it is almost a pity to destroy the illusion; but it appears to have been borrowed by his historian from a Danish story, related by Saxo-Grammaticus, who wrote in the twelfth century: this identical feat, with scarcely any variation except name and

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[1] Percy's Ancient Poems, vol. i. p. 143.

[2] The identical bow and arrows, said to have been used by Tell, are still shown at Zurich. (Coxe's Switzerland, vol. viii. p. 81.)

place, is stated to have been performed by Toko, a Dane.[1]

The tyrant Domitian was so expert an archer, that he would frequently cause one of his slaves to stand at a great distance, with his hand spread as a mark, and would shoot his arrows with such exactness as to strike them all between his fingers.

The story of Aster of Amphipolis and Philip is well known; but it would be unprofitable to multiply examples further. The extreme range of an English bow was said to be about 600 yards, but the greatest distance known in modern times varies from 300 to 500 yards. The Turkish ambassador, when in England, sent an arrow upwards of 480 yards in the presence of several members of the Toxophilite Society; and his bow, which is made of horn, is now in their possession: this is undisputed; and a few other shots exceeding this by twenty or thirty yards, are equally authentic.

The pellat bow of India is merely a light bow, strung double, with a cradle of leather in the middle to receive a clay ball dried in the sun, with which the natives can bring down birds in their flight at forty or fifty yards.

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[1] "Tales and Popular Fictions," &c. by Thomas Keightley. 1834.

While speaking of archery, I must not omit our own countryman, that "honest thief and outlaw," Robin Hood, whom Camden calls "prædonum mitissimum" (the gentlest of thieves); his exploits with those of his companions fill an interesting volume, called "The Life of Robin Hood," by Mr. Joseph Ritson the antiquary, to which I must refer those who are curious in these matters.[1] Drayton in his Polyolbion says, —

"All made of Spanish yew,
Their bows were wond'rous strong,
They not an arrow drew,
But was a cloth-yard long."

Again, —

"And shot they with the round,
The square, or forked pile,
The loose gave such a twang,
As might be heard a mile."

"Tradition," says Master Charlton[2], "informs us, that Robin Hood and Little John have frequently shot an arrow a measured mile[3], which, it is supposed, no one either before or since was ever able to do," always excepting the story

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[1] Life of Robin Hood, 2 vols. 8vo. 1795; reprint, 1 vol. 1820.

[2] History of Whitby, Yorks. 1779, p. 146.

[3] From the top of Whitby Abbey to Whitby Laths, one mile and one yard.

told by Firdousi, the Homer of Persia, and repeated by other grave historians, who assert that, in ancient times, when Menoocheher, the grandson of Feridoon, made peace with Afrasiab the Scythian invader, one of the articles of the treaty was, that Persia was to have all the the country in a north-east direction over which an arrow could be shot from Demavend.[1] A hero called Arish ascended to the top of the mountain, and such was his miraculous prowess, that he sent an arrow to the banks of the Oxus, a distance of between *five and six hundred miles.* Monarchs in those days, we are assured, were more scrupulous than at present in performing their treaties, and the country was faithfully ceded. One Persian historian who relates this fact, admits that it is incomprehensible, but at the same time adds that he deems it his duty to give it as received from former writers, who state, that the arrow which was discharged at sunrise did not fall till noon.

Another author of high reputation informs us that the "festival of the arrow" on the 13th of October, which is still kept by the followers of Zoroaster, is in consequence of this event.[2]

Many learned discussions have taken place re-

[1] A lofty mountain near Tehran.

[2] Sketches of Persia, by Sir J. Malcolm, vol. ii. p. 104. Richardson's Persian and Arabic Dictionary.

specting this wonderful arrow: almost all admit it must have been of gold; but some sceptical commentators on this passage of ancient history are of opinion, that the story of the golden arrow flying from the Demavend to the Oxus, was nothing more than a bold metaphor to express that the Persians conquered that extent of country by their skill in archery.

This being the longest shot on record, possibly gave rise to our figurative expression of "*shooting with a long-bow.*"

Why archery should continue so long in use after the invention of gunpowder will excite no surprise, when we reflect, that within a century and a half, muskets were the most unwieldy implements of war.

The principal society of this kind now existing is the "Royal Company of Archers of Scotland," which arose about the time of James I., and claims the privilege of forming the body-guard of the king whenever he may visit that country.[1]

Archery has of late years become fashionable, and much patronised by the ladies, who cannot

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[1] For more particular information respecting the laws relating to Archery, &c. see Stowe, vol. ii. b. 5. p. 218. and vol. i. b. 1. p. 250.; Grose, vol. i. p. 140—154.; The Bowman's Glory (1682), &c.

enjoy a more healthy amusement, or one better calculated to improve the figure, or to display it to the greatest advantage.

The cross-bow, although of modern date when compared with the antiquity of the long-bow, must have been known more than seven centuries. It was for a considerable period employed in the armies of most civilised nations, but never esteemed by the English so much as their favourite weapon the long-bow, in the use of which collectively they appear to have excelled almost every other nation.

Our ancestors confined the use of the cross-bow principally to the defence of fortified places and to sea fights; indeed, after the reign of Henry III. it was studiously discouraged in England, although the French continued to employ it to the great injury of their countrymen long after the superiority of the English long-bow had been fully established. Bayle, explaining the difference between testimony and argument, uses this simile,—"Testimony is like the shot of a *long*-bow, which owes its efficacy to the force of the shooter; argument is like the shot of a *cross*-bow, equally forcible, whether discharged by a dwarf or a giant."

The cross-bow[1], or arbalest, is called in Latin

[1] Grose, Hist. Eng. Army, vol. i. p.155.

arcus balistarius, or *balista manualis;* and in French, *arbalète:* by some, it is said to be of Sicilian origin; others ascribe its invention to the Cretans. It is supposed to have been introduced into France by the first Crusaders, and is mentioned by the Abbé Suger in the life of Louis le Gros, as being used by that prince in the beginning of his reign, which commenced in the year 1108.[1] Verstigan seems to attribute the introduction of this weapon into England to the Saxons under Hengist and Horsa, but cites no authority in support of that supposition.[2] William the Conqueror appears to have had cross-bows in his army at the battle of Hastings, and the Genoese were considered very skilful in the use of this instrument, a great number of them being in the French service at the battle of Cressy.

The effects of this weapon were deemed so fatal and cruel, that the use of it was forbidden by the Second Lateran Council in 1139[3], under the penalty of an anathema, as hateful to God and unfit to be employed among Christians; which prohibition was confirmed by Pope Innocent III. It was nevertheless introduced into

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[1] Père Daniel, Hist. de la Milice Française, tom. i. p. 425.

[2] Verstigan is in fact no authority himself.

[3] In the reign of Stephen.

our armies by Richard I., who being slain by a *quarrel* shot from one of them at the siege of the castle of Chaluz in Normandy, his death was considered as a judgment from Heaven, inflicted upon him for his impiety.

Notwithstanding this example, the cross-bow continued to be much used by the British troops; and in the list of the forces raised by Edward II. against the Scots, the cross-bow men make the second article in the enumeration of the different kinds of soldiers of which this army consisted.

The cross-bow kept its footing in our armies so late as the year 1572, when Queen Elizabeth, in a treaty with Charles IX. of France, engaged to furnish him with 6000 men, part of them armed with long-bows, and part with cross-bows; and in the attack made by the English on the Isle of Ré in 1627, it is said some cross-bow men were in that army; since which period they have been entirely laid aside, except for amusement.

The ancient cross-bows were of various kinds, suited to circumstances: the stirrup cross-bow, which was of the largest description, and used for defending forts or walls, was wound up by means of compound pulleys, with a machine called a moulinet, one foot being placed in the stirrup.

Other kinds were called latches and prods,

the latter being used for deer shooting: the smaller kinds were bent by the assistance of a lever called the goat's foot, in consequence of its being cloven or forked in that part which rested on the cord. The bows were usually made of steel, though sometimes of wood or horn, and the missiles discharged from them were either bullets, stones, arrows, or short darts called *quarreaux*, or corruptly *quarrels*, from the shape of their heads, which were square pyramids of iron; these were feathered (as it was called) with wood, brass, or leather. These quarrels were peculiarly adapted to penetrate iron armour. An ordinary cross-bow[1] would kill *point blank* at about sixty yards; but, if elevated, at seven or eight score yards. Cross-bow men were frequently mounted on horse-back, their dress and arms being similar to the archers. The form of this weapon is evidently extremely inconvenient for carriage, and it is not easily secured from wet; while, on the contrary, the long-bow is light, portable, and capable of being charged instantaneously[2]: it is not, therefore, surprising, that troops who solely used the latter most effectual weapon, should generally

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[1] Sir John Smith, Instructions and Observations, &c. p. 204.

[2] Barrington's Observations on Archery.

obtain the victory, even when opposed to great superiority of numbers. A very ingenious self-charging cross-bow has recently come under my observation; it is of Cingalese manufacture, and whether common in Ceylon, or merely the ingenious contrivance of some native, I am at present unable to determine; but it strings itself, and discharges two arrows each time in rapid succession until the magazine is exhausted, which contains twelve, and it may be replenished in a moment.[1]

I must now return to periods more remote, in order to describe some of the warlike engines constructed by the ancients on the principles of the bow and sling; and as the word artillery was formerly used in a different sense to its present acceptation, it may be necessary to premise, that in its original meaning it signified archery; but has since been extended to include all the offensive apparatus of war, and even to include the officers and men.

In the time of Dryden, it was figuratively employed by him and by contemporary poets to express those bright flashes from female eyes which were supposed to be as destructive to the beholders as artillery, and consequently in the language of those days called the "*artillery of*

[1] The original is in the United Service Museum, Whitehall.

the eyes;" but the latter extension of the term does not form any part of my subject. I will, therefore, proceed to observe, that the first intimation of trees being cut down "to build bulwarks against the city until it be subdued," occurs in Deuteronomy, xx. 19, 20. (B. C. 1451); but the earliest precise mention of artillery is in 2 Chronicles, xxvi. 15., where we are told that Uzziah[1], who began his reign 809 years before the Christian æra, "made in Jerusalem engines invented by cunning men, to be upon the towers and upon the bulwarks, to shoot arrows and great stones withal." This is particularly mentioned by Josephus[2], who relates that Uzziah "made many engines of war for besieging cities, such as hurl stones and darts, with grapplers, and other instruments of that sort." He must therefore be considered the inventor of them; and from that time they began to be employed in attacking and defending towns.

If we may judge by the writings of Homer, the Greeks in their early times did not possess one military engine calculated to shake a wall, unless we conceive with Pliny, that the fable of

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[1] The son of Amaziah, who reigned B.C. 840—811.

[2] Antiquities of the Jews, b. ix. c. 10. Calmet's Dissertation sur la Milice des Anciens Hebreux.

the wooden horse, which caused the downfall of Troy, was merely a poetical metaphor for a battering-ram, which is far from being improbable, since nothing could be more natural than to use a beam of wood to burst open a gate, or overthrow a wall.[1]

According to Thucydides[2], the primitive Grecians were unacquainted with the use of walls; their possessions lay open to all invaders; the people led a roaming life, wandering from one part of the country to another. In this unsettled state they remained for several ages, until some superior minds suggested the contrivance of surrounding their property by walls. This was at first conceived to be so far above human capacity, that the gods were called from their blessed mansions to undertake it; but once secured within walls, they considered themselves safe from all assaults, and had not a weak opposition within been sufficient to repel a greater force of invaders, such a town as Troy could not have held out for ten years against 100,000 besiegers, who on their part appear to have taken sufficient time to discover any means of forcing open the gates.

Many cities were fortified with walls previous to the taking of Troy. Thebes in Bœotia was

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[1] Potter's Archæologia, vol. ii. p. 89. [2] Lib. i.

besieged and taken by the fathers of those chiefs who were engaged in the siege of Troy; and in the catalogue of the Greek forces[1], Athens, Tyrins, Mycenæ, Cleonæ, Arpi, and some others, are described as fortified places.

It appears highly probable that the *aries*, or battering-ram, being the simplest of all the ancient engines, was also the earliest. The name is derived from being usually armed at the striking end with iron, in the form of a ram's head. The instrument itself might have been suggested by the well-known butting character of that animal. Some persons have supposed that the walls of Jericho, mentioned in the Book of Joshua, were beaten down by this instrument, the rams' horns by which they were overthrown being the horns of the battering-ram. Of these engines there were several kinds: the first was simply a beam or mast, carried by a number of men, and propelled by their united efforts end foremost. When of larger dimensions it was suspended to a frame, and worked by means of ropes or handles. Another sort differed only in being mounted on wheels and enclosed with hurdles, covered over with raw hides at top, to protect the soldiers while working. Some of these were of immense

[1] Iliad, B.

dimensions. Plutarch[1] mentions one used by Mark Anthony in the Parthian war, which was 80 feet long; and Vitruvius, who ascribes the invention to the Carthaginians, affirms that they were sometimes from 100 to 120 feet in length; being, in fact, the largest trees that could be procured, hooped with iron rings, and having iron heads of immense weight bolted to them.

Josephus observes[2], "there is no tower so strong, or wall so thick, as to resist the repeated assaults of this powerful machine;" and adds, "that one of Vespasian's rams, the length whereof was only 50 cubits[3], which came not up to the size of many of the Grecian rams, had a head as thick as ten men and twenty-five horns, each of which was as thick as one man, and placed a cubit's distance from the rest: the weight, as was customary, rested on the hinder part, and was no less than 1500 talents.[4] When it was removed without being taken to pieces, 150 yoke of oxen, or 300 pairs of horses and mules, laboured in drawing it, and 1500 men employed their utmost strength in forcing it against the walls." There was a fourth kind,

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[1] Life of Anthony. [2] Wars of the Jews.

[3] The Jewish cubit was 21·888 inches, therefore 50 cubits would be equal to about 91 feet.

[4] The talent = 3000 shekels = 114 lbs. troy.

which ran on wheels, pointed in front and hollow within, used for splitting or bursting open gates, and was pushed forward by the soldiers.[1]

Various stratagems were resorted to by the besieged to elude the power of these machines: fire, stones, and missiles of every description, were showered upon them; sacks filled with chaff or wool were lowered down from the walls to deaden the blow, and they were frequently overthrown by undermining the foundations; the ropes were cut by long scythes fastened to poles; and if no hope remained of defending the walls, new forts were often raised within.[2]

The effect of the battering-ram depending almost wholly on its length and weight, the velocity was necessarily very small, being worked by manual labour only. It may not, therefore, be uninteresting to compare the power of this engine with that of modern artillery. It being understood that momentum or power, in mechanics, is estimated by multiplying the weight of the projectile by its velocity, therefore, theoretically, any body, however small, may be made to strike as forcible a blow as any other

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[1] Vegetius, de Re Militari.

[2] Vitruvius. Josephus. Potter's Archæologia. Rees's Cyclopædia, art. *Aries*.

body however large, provided it be possible to increase the velocity of the smaller body in the same proportion as the weight of the greater bears to the weight of the smaller: for example, suppose a 3-pounder cannon-ball to move at the rate of 1500 feet in a second, then $3 \times 1500 = 4500$; and another ball weighing 50 lbs. to move with a velocity of 90 feet in a second, then $50 \times 90 = 4500$, as before; therefore the 3 pound ball and the 50 pound ball would each strike any object placed at equal distances with the same force. On these principles Dr. Desaguliers[1] has demonstrated, that the momentum of a battering-ram 180 feet long, 28 inches in diameter, with a cast-iron head of one ton and a half, the whole ram with its hoops weighing 41,112 lbs., and moved by the united force of 1000 men, would only be equal in effect to that of a ball of 36 lbs. weight, shot point blank from a cannon.

Mr. Attwood comparing the effect of a ram having its metal extremity equal to a 24-pounder shot, with a ball of 24 lbs. weight, observes, that in order to their producing the same effect in penetrating or making a breach in a wall, the weight of the ram must exceed that of the

[1] Lectures, vol. i. p. 65.

cannon ball in the proportion of the square of 1700 (the velocity that could be given to the ball) to the square of the velocity with which the ram could be made to impinge against the wall expressed in feet: estimating this at ten feet in a second, the proportions of the weight will be about 2,890,000 to 100, or 28,900 to 1; therefore the weight of the ram must be 346 tons. In this case the battering-ram and the cannon ball, moving with the velocities of 10 and 1700 feet in a second, would have the same effect in penetrating any obstacle; but as the weight of the ram was probably never so great as the above supposition assumes it to have been, the force of a cannon ball to make a breach in walls must exceed that of the ancient aries: but the momentum of this, or the impetus by which it communicated a shock to the whole building, was far greater than the utmost force of cannon balls; for if the weight of the ram were no more than 170 times greater than that of a cannon ball, each moving with its respective velocity, the momenta or forces of both would be equal; but as the weight of these ancient machines was certainly much greater than 170 times that of our heaviest cannon balls, their momentum, or impetus, to shake or overturn walls and demolish buildings, was much superior to that which is exerted by the modern artillery. And since

the strength of fortifications will in general be proportionate to the means which are used for their demolition, the military walls of the moderns have been constructed with less attention to their solidity and massive weight than the ancients thought to be a necessary defence against the aries; that sort of cohesive firmness of texture which resists the penetration of bodies, being now more necessary than in ancient times.[1]

The ram was frequently used in the fourteenth century. Sir Christopher Wren employed it in demolishing the walls of the old church of St. Paul previously to rebuilding it, and found no machine so well adapted to his purpose: gunpowder was also employed, but Sir Christopher was prevented from continuing the use of it in consequence of an accident and the fears entertained by the surrounding inhabitants, who petitioned for its discontinuance.

The earliest instances of projectile machines in profane history appear to be at the sieges of Rhegium and Motya by Dionysius (B. C. 388, 370), where, having battered the walls with his rams, he advanced towards them towers rolled on wheels, from whence he galled the

[1] Rees's Cyclopædia, art. *Aries*.

besieged with continual volleys of stones and arrows, thrown from his *balistæ* and *catapultæ*.[1]

The next memorable instance[2] is the siege of Rhodes by Demetrius Polyorcetes (B. C. 303), who brought forward a newly invented machine called *Helepolis* (Ἑλέπολις, taker of cities), with a variety of other engines, and employed in the management of them 30,000 men; but the siege was raised after continuing a whole year, although Grecian ingenuity was exhausted in the invention and improvement of artillery. These engines, when used at the siege of any city, were usually carried on great wooden turrets, or towers, first invented by Demetrius, who, having taken several towns by the help of them, was surnamed *Polyorcetes* (Πολιορκητὴς, besieger of cities); and from their use in battering, they were called *Helepolis* (Ἑλέπολις). Vitruvius[3], Plutarch[4], and Diodorus[5], have described this machine. It was drawn on four wheels; each of its sides was forty-five cubits, and its height ninety cubits; it was divided into nine stages or compartments, each containing divers engines for throwing darts, stones, and arrows. Another instance occurs in Livy[6]: when Hannibal

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[1] Ancient Universal History, vol. vi. p. 401.

[2] Diodorus Siculus, lib. xx. [3] Lib. xx. [4] Lib. xx.

[5] Lib. xiv. [6] Lib. xxi. c. 7., and lib. xxvi. c. 46, 47.

besieged Saguntum (B. C. 219), the Saguntines hindered his soldiers from using the battering-ram by an incessant hurling of stones, darts, and other missiles. The same author supplies us with a curious inventory of the warlike engines which Scipio eight years afterwards found among the stores of Carthagena.

Two years previous to this, Marcellus[1] had laid siege to Syracuse: Archimedes was at that time residing there, and at the earnest intreaty of Hiero, king of Sicily, he exerted all the powers of his mind in the invention of artillery and warlike engines. Marcellus had brought with him an amazing engine on eight galleys, called *sambuca*[2], which the mathematician destroyed by discharging single stones of enormous weight upon it, while it was at a considerable distance from the walls. Vegetius observes, that it was called *sambuca*, from its resemblance to the *cythera*, or harp; "for as in the harp there are cords, so in the beam, which is placed near the town, there are ropes which let down a bridge from the higher part, so as to take hold of the wall, and immediately the warriors going out of

[1] Plutarch, Life of Marcellus, vol. ii. p. 240.

[2] So called from its resemblance to a musical instrument of that name.

the tower and crossing the bridge, invade the walls of the city. The bridge which is suddenly protruded from the tower to the wall is called *exostra*."[1] Plutarch states, that "at last the Romans were so terrified, that if they saw but a stick or a rope put over the walls, they cried out, "Archimedes was levelling some machine at them," and immediately turned their backs and fled. The chief instruments he used were balistæ, scorpions, and a kind of crane, lowered by a lever, which hoisted the Roman vessels by the prow, and plunged them to the bottom of the sea. He left no account in writing of these military engines, because he considered all attention to mechanics mean and sordid, and reckoned such inventions merely as the amusements of geometry.

It would be useless to enumerate the ancient sieges at which such engines were employed; in fact, no siege could be successfully conducted without them; and it is probable that at each some improvement, or alteration, suited to circumstances would take place. Tacitus[2], however, mentions an extraordinary engine, which the fifteenth legion used with dreadful execution at the battle of Cremona against the troops of

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[1] De Re Militari. [2] Hist., lib. iii. c. 23—29.

Vespasian. It was a balista of enormous size, with which the Vitellians discharged stones of weight sufficient to crush whole ranks at once; and we are told that inevitable ruin must have followed, had not two soldiers signalised themselves by approaching undiscovered to the battering engine, and cutting the ropes and springs. At length, after a vigorous assault from Antonius, the Vitellians unable to resist the shock, and enraged at their disappointment, in a fit of despair rolled down the engine on the heads of the besiegers. Numbers were crushed by the fall of so prodigious a mass; but the machine drew after it a neighbouring tower, the parapet, and part of the wall, which afforded the besiegers easier access to the city. Josephus relates[1], that being commander at the siege of Jotapata[2] by Vespasian, "a stone from one of the Roman engines carried the head of a soldier who was standing by him three furlongs off." He estimates the number of engines that were set about the city at 160, and says, "lances were thrown with a great noise, and stones of the weight of a

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[1] Wars of the Jews, b. iii. c. 7.

[2] Jotapata, a town of Phœnicia, in the vicinity of Ptolemais: it was defended by Josephus, but at length taken by Vespasian (A.D. 67): its defence lasted seven weeks: 40,000 Jews were slain.

talent, together with fire and a multitude of arrows." At this siege, and at that of Jerusalem (A.D. 70), the dead bodies of men and horses were thrown from the machines to inspire the besieged with greater terror.[1]

The Romans had regular batteries of balistæ and catapultæ: the former were used to discharge stones and the latter arrows, although both names have been used promiscuously, some authors contending for the contrary opinion. The derivation of these names, however, appears to indicate the particular purposes to which each was originally applied, balista being derived from the Greek βάλλω (I throw), or βάλλειν (to throw): and catapulta from the preposition κατὰ (down), and πέλτη (a spear, or dart). It appears however that, although the term balista is of Greek origin, it was not used in Greece, though this engine was known there.[2]

According to Vitruvius, the balista was made after divers manners, though used for the same purpose: one sort was framed with levers and bars, another with ropes and pulleys, some with a crane, and others with cog-wheels. Its structure

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[1] Wars of the Jews, b. iii. c. 9.

[2] Archæologia. Grose, Hist. Eng. Army. Ammianus. Bishop Wilkins' Math. Magic.

and effects were reducible to the principles either of the bow or sling; whence some writers call it *funda* and *fundibulus*.

The balista must have been heavier and more difficult to carry than the catapulta, because there were always in the army a greater number of the latter. Livy says, there were 120 great and 200 small catapultæ taken at the siege of Carthage, with 33 great and 52 small balistæ; and Josephus mentions the same difference among the Romans, who had 300 catapultæ and 40 balistæ at the siege of Jerusalem.

The earliest form[1] of the balista appears to have been a very long beam, suspended in a frame, on a centre of motion, one end being considerably longer than the other: to the short end was attached a great weight, such as a chest filled with earth and stones; to the longer end a sling was affixed, in which a stone was placed after being drawn down, and on being suddenly let go, the long end flew up and discharged the stone with great violence. Catapultæ were constructed to discharge a flight of arrows at once, by placing them on a rack and causing a strong plank, previously drawn back, to strike against their ends: but the more perfect engines of the

[1] Bishop Wilkins.

Romans, as minutely described by Vitruvius and others, were all dependent on the elasticity of twisted cords, made frequently of flax or hemp, but sometimes of the sinews and tendons of animals; those in the neck of the bull and in the legs of the deer species were particularly recommended: but it is stated, that ropes formed of human hair were preferred to all others, as possessing much greater strength and elasticity. These latter engines were immensely powerful bows, drawn back by means of capstans, levers, or pulleys; the catapulta having only a single cord for the arrow, and the balista a broad band, formed of several ropes, to project the stone, which was placed in a kind of cradle like a cross-bow. Some of them threw beams of wood and lances of twelve cubits in length; others stones, that weighed 360 lbs. Athenæus speaks of a small catapulta, only one foot long, which threw an arrow half a mile; and Ammianus says, the arrows were sometimes set on fire by the swiftness of their motion.[1] Having constructed working models of these engines myself, I am confident, that however disposed some ancient writers may be to exaggerate,

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[1] Rollin, Arts and Sciences, vol. ii. p. 52. Tacitus, Annal. xv. 9. and Hist. iv. 23.

these engines did not fall far short of producing the effects described.

Their introduction into this country is undoubtedly to be ascribed to the Normans, whom William of Malmsbury describes as having a peculiar delight in war.[1] Machines for throwing stones occur as early as the battle of Hastings (1066); and Robert de Brunne, in his wars against the Saracens, informs us, that when Richard I. set out against the Holy Land, he had in his barges and galleys mills turned by the wind, which, by the force of the sails, threw fire and stones.

Our ancestors appear to have derived considerable knowledge in consequence of the Crusades, as they obtained some composition from the Saracens, which resembled the Greek fire, and which could only be extinguished by smothering it with dust or vinegar. This composition, similar to the modern *roche-à-feu*, was often thrown in pots from the balistæ; and it was by this device that the Black Prince set fire to Remorentine. Camden informs us, that with the mangonels, trebuchets, and briccolas, our forefathers used to cast forth mill-stones; and

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[1] William of Malmsbury, lib. iii. p. 57. William of Poictou, &c. Grose.

Holinshed relates, that when Edward I. besieged Strively Castle, he caused certain engines to be made, which shot off stones of two or three hundred weight. Bombs were also thrown from the balistæ. The names of all the projectile engines used in the eleventh and twelfth centuries are thus enumerated by Grose: — the ram, balista, catapulta, onager, scorpion, mangonel, trebuchet, petrary, robinet, mategriffon, briccolla, bugle or bible, esprigal, matafunda, ribaudequin, engine-à-verge, and war-wolf. Not only the form but the method of using many of them is now extremely doubtful, though it is highly probable that the greater number were merely modifications of those already described, or the same machines under different appellations. Under peculiar circumstances, the ancient engines may be employed with advantage in modern warfare. A balista was constructed at Gibraltar under the direction of General Melville, at the desire of Lord Heathfield, for the purpose of throwing stones just over the edge of the rock, in a place to which the Spaniards used to resort, and where shells thrown from mortars could not injure or annoy them. An engraving of this machine is in Rees's Cyclopædia.

PART II.

ON EARLY FIRE-ARMS, ETC.

THE history of Gunpowder might with propriety form the prelude to modern artillery, but as it is universally known that the existence of the latter is wholly dependent on the discovery of the former, I consider it advisable to proceed with artillery, and leave the history and manufacture of gunpowder to follow, in order to render each subject more complete and uninterrupted.

Although there may be some doubt as to the precise meaning of the terms employed, it is generally supposed by writers on this subject, that by "*crakys of war*," mentioned by John Barbour, archdeacon of Aberdeen, in his metrical life of Robert Bruce, cannon of some description were implied. He states that they were used by Edward III. in his first campaign against the Scots in 1327. This is the earliest instance recorded, and it is certain that about this period they were first employed in warfare, gunpowder having been proposed for the destruction of armies many years previous. Vilani

and Rapin say, that the English first made use of cannon in France at the battle of Cressy (1346), before which they were unknown in that country.[1] Rapin observes, that "four pieces, which they had placed on a hill, did so much execution amongst the French troops, and inspired them with so much terror, that part of the success of the day has been attributed to the surprise occasioned by this novelty." Father Daniel, however, says, the French used them in 1338; and gunpowder is stated to have been used at the siege of Algiers in 1342.[2] The moral effect produced by the early fire-arms was probably much greater than their destructive powers. In 1378, when the English unsuccessfully besieged St. Malo, 400 cannon are said to have been employed; but these are supposed to have been of the smaller kind, called hand-cannon or culverins, which were carried by two men, and fired from a kind of tripod, or rest, fixed in the ground.

Bolts[3] and quarrels were shot from cannon in

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[1] Hist. d'Angleterre, tom. iii. p. 196. In this battle the Prince of Wales obtained the plume and motto *Ich Dien* from the King of Bohemia.

[2] Rees's Cyclopædia.

[3] Dr. Meyrick, p. 118. Anderson's Hist. of Commerce, vol. vi. p. 351.

the reign of Henry V. (1413): these were succeeded by stones, as in 1418 Henry ordered the clerk of the works of his ordnance to procure labourers for the making of 7000 stones for the guns of different sorts, in the quarries of Maidstone in Kent.

Guicciardini[1] relates, that so large a portion of time elapsed between the loading and discharging of the great guns, that the besieged had sufficient time to repair, at their leisure, the breaches made in the walls by the shock of the enormous stones thrown from them: he alludes to the cannon employed at the siege of Constantinople by Mahomed II. in 1453, which were formed of bars of iron, hooped together lengthways with iron rings, and as they immediately succeeded the balistæ, they were used like them for throwing immense masses of stone, some of which weighed 1200 pounds. They could not be discharged more than three or four times in a day. Gibbon remarks, that the siege of Constantinople, which terminated the Greek empire, May 29. 1453, was distinguished by the re-union of ancient and modern artillery: the small arms of the Christians discharged five or even ten balls at the same time, as large as

[1] Historia d'Italia, tom. i. p. 24. edit. Venet. 4to.

walnuts; and one piece of ordnance made for the Turks by Urban, a Dane, cast a stone bullet weighing 600 lbs., which could be discharged seven times a day; but it ultimately burst.

As knowledge increased, improvements were made, and the size of cannon was reduced to admit of casting them in iron and bronze to receive iron bullets, which were first used in England in 1550.[1] Guicciardini says that, as early as 1380, the French were able to procure for the invasion of Italy a great number of brass cannon, mounted on carriages, and drawn by horses instead of oxen: these pieces threw balls of from forty to sixty pounds' weight, and could always keep pace with the army. At that period, scarcely any attention was paid by military men to mathematical or mechanical knowledge; therefore, it is by no means wonderful, that so little alteration should have been produced in the art of war by the application of gunpowder; the great expense and difficulty of procuring it, added to the extreme awkwardness of their artillery, account for the preference frequently given to the old machines. Accordingly, we find the tripget employed in the fourth year of

[1] Rees's Cyclopædia, art. *Chronology*.

the reign of Henry V., and so late as the time of Elizabeth (1558 - 1600) the strength of our armies consisted in the archers.

Bishop Wilkins[1] enables us to form some idea of these unwieldy cannon, as well as of the strength, or rather weakness, of the powder: he says, "the price of these gunpowder instruments is extremely expensive, as may be easily judged by the weight of the materials, a whole cannon weighing commonly 8000 lbs., and requiring 90 men or 16 horses for the draught of it, with a charge of 40 lbs. of powder, and a ball weighing 64 lbs." The length of some of them was immense: one taken at the siege of Dien in 1546, by Don John de Castro, is now, or was not long since, in the Castle of St. Julian de Barra near Lisbon; its length is 20 feet 7 inches, diameter in the middle 6 feet 3 inches, and it threw a ball of 100 pounds' weight: an Hindustan inscription on it states, that it was cast in 1400.[2]

These early cannon were called *bombardæ*, from βόμβος, on account of the great noise their firing occasioned; and it was not unusual to give strange names to them: thus Louis XII. had

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[1] Math. Magic, c. xix. p. 137. (1680).

[2] Rees's Cyclopœdia, art. *Cannon*.

twelve brass ones, cast in 1503, of enormous size, which he named after the twelve peers of France; the Spaniards and Portuguese christened theirs after their saints; and the Emperor Charles V. had twelve when he went against Tunis, which he called the Twelve Apostles.

At Dover Castle there is a 60-pounder, named Queen Elizabeth's Pocket Pistol; and a very large one, called Mons Meg, was brought from Edinburgh Castle to the Tower of London, but restored to its original station by order of George IV. in 1829: there is, however, a model of it in wood still in the Tower. At the Castle of St. Angelo, at Rome, there is an uncommon 70-pounder, made of the nails that fastened the copper plates which covered the ancient Pantheon, with this inscription, "Ex clavis trabalibus Porticus Agrippæ."

In England the science of artillery occupied attention as early as 1544. Lord Herbert observes that Henry VIII. had himself invented small pieces of artillery to defend his waggons.[1]

In France the use and practice of artillery had not advanced beyond its infancy in the reign of

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[1] Strutt's Manners and Customs, vol. ii. p. 32. Glennie's Hist. of Gunnery. Hist. of England, Henry VIII.

Henry III. (1574).[1] D'Etrées, who was master-general of the ordnance during the siege of Calais by Francis Duc de Guise, was the first who made any progress in the construction of batteries. Anterior to his time continual accidents occurred from the bursting of cannon, and it was usual to cool them with vinegar previous to reloading.

It is stated by Voltaire, in his "Essai sur l'Histoire Universelle," that bombs were first used at sea by the French in the bombardment of Algiers (Oct. 28. 1681) in the reign of Louis XIV., previous to which it was thought impossible to use mortars any where but on land. The proposer, Bernard Renaud, was ridiculed for supposing such a plan practicable, when he offered it to Colbert the minister. This is, however, usually the fate of those who precede their own age a few years in intellect. Gradually the length and diameter of cannon were much reduced, experience having determined how much they might be diminished in weight without injury to their safety or to the effects they were intended to produce; which proceeding has been continued to the present day,

[1] Mémoires d'Artillerie, 2 vols. 4to. (1588).

many of our 24-pounder guns being now bored up to 32-pounders at Woolwich.

The materials of which cannon have been composed are various; besides metals; wood, leather, rope, and even water, in the form of ice, have been employed in their construction. In the arsenal at Venice there is a mortar made of a coil of rope covered with raw hides, intended to throw a stone bullet; and, in 1740, several cannon were cut out of solid ice at St. Petersburgh, and fired repeatedly with ice bullets without bursting. A variety of early and recent specimens of curious artillery may be seen in the arsenal and in the rotunda at Woolwich.

The largest piece of ordnance known in modern times was the "monster mortar," recently cast at Liege, and used at the siege of Antwerp in 1832: it was only discharged fourteen times; two of the shells fell into the citadel, burying themselves so deeply that they did no injury; the others passed over it. This mortar burst not long afterwards, while making some experiments with it before the king of France.

The heaviest piece of ordnance I am aware of is the Bijapoor gun in India, which weighs about forty-two tons. An Italian of Otranto, who served in the Mogul armies, under the title of Rúmi Khan, had this gun in his park of artillery,

and used it at several battles, occasionally firing sacks of copper coins out of it.[1]

This part of the subject, as well as the preceding, might be enlarged to an almost unlimited extent, but I only desire to give such heads of information as may enable those who desire it, to prosecute the investigation further.

It would, however, be improper to omit mentioning the new cannon first proposed by Mr. Monk of Woolwich Arsenal, and cast from his own drawings and models, as it proves how much more may be done by the combination of practical and theoretical knowledge than can be effected by either separately.

Mr. Monk's plan appears at first sight to be a very simple one, and one that would naturally occur to any man conversant with gunnery; but it was not adopted until several years after he proposed it. His plan is merely to remove a quantity of useless metal from before the trunnions, and increase the thickness considerably, where alone it is required, at the breech end. A 56-pounder cannon, cast on this plan, was tried at Deal in 1839, 11 feet long, diameter of bore 7·6 inches, weight 98 cwt., windage 0·175,

[1] Journal of the Royal Asiatic Society of Bengal, vol. i. p. 70. Captain Twemlow, ~~Bombay~~ Artillery. Bombay Transactions, vol. iii. Colonel Sykes.

at an elevation of 32°, with a shot weighing 62½ lbs.[1] and 16 lbs. of powder; the range was 5720 yards, or just *three miles and a quarter*[2]; the greatest distance ever attained by any projectile with any charge whatever, and the greatest velocity; the whole time of flight being only 30¼ seconds, which is estimated at 2100 feet in the first second of time. Guns cast on this plan, although several hundred weight lighter altogether, recoil less than those on the old plan, with equal charges of powder and ball, in consequence of the weight of metal being properly distributed. One remarkable fact attended these experiments, namely, that by increasing the windage a little, the range was increased also, contrary to the universally received opinion: but this may be explained by the circumstance, that with very great velocities and long guns, the column of air to be displaced before the ball quits the gun is considerable, and is condensed so rapidly, that it offers immense resistance to the passage of the bullet if it fit the bore

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[1] A cast-iron shell filled with lead was used, which weighed 62½ lbs.

[2] The French threw shells into Cadiz, nearly the same distance, but this range was effected by means of enormous mortars, and the largest charges of powder ever employed in modern times: the time of flight was about 50″.

closely ; but by reducing the size of the ball, and thus increasing the windage, the air has more space to rush round it, and the ball escapes with greater facility.

Having concluded my observations on great guns, I return to the period when hand-guns or small fire-arms were first introduced into this country, which appears to have been in 1471, when Edward IV. landing at Ravenspur in Yorkshire, brought with him among other forces 300 Flemings armed with hand-guns. This is fifty years before the date usually assigned for their introduction, Mr. Anderson and other writers placing that event at the siege of Berwick in 1521 ; soon after which, they were generally adopted in England.[1]

The protector Somerset aware of the importance of fire-arms, had above 3000 foreigners in his pay, of whom the greater part were musketeers.[2] In 1555, the Spaniards are said to have used them under Philip II. (and at this period the Spanish armies were still considered the finest

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[1] Anderson's Hist. of Commerce, vol. i. p. 351. Leland's Collectanea, vol. i. p. 721. Grose, Hist. Eng. Army, vol. i. p. 160.

[2] Andrew's Hist. England. James's Milit. Dict.

in Europe); but these muskets were so heavy that they could not be presented without the assistance of staves shod with iron, having a fork at the top to rest the barrel on. Various attempts were made to convert this rest into a defence against cavalry, while the musketeer was loading, by affixing a spike to the head, or enclosing a short dagger in the shaft, so as to fly out on touching a spring. Rests thus armed were called "the Swedish or Swine's feathers."[1] These muskets at first had no lock whatever, but were fired like cannon by applying a lighted match. When they were reduced in weight and improved by the invention of the *match-lock*, so that they could be discharged from the shoulder without rests, they were called *calivers*, the old muskets being confined to sieges, and resembling the arms now called *wall-pieces*, which are still used in India. The caliver appears to have been intermediate between the musket and the arquebuse: by a passage in Shakspeare[2] it seems that calivers were used in his time for shooting wildfowl: Falstaff says, speaking of his

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[1] Grose, vol. i. p. 165. De Limière, Hist. Louis XIV. vol. vi. p. 88. Strutt's Manners and Customs, vol. viii. p. 91. Turner's Pallas Armata, p. 176.

[2] Henry IV. act. iv. sc. 2.

soldiers, "such as fear the report of a caliver worse than a struck fowl, or a hurt wild-duck."

Many writers consider the arquebuse to be the most ancient fire-arm mounted on a stock, and place the invention of it about the year 1500; it succeeded the hand-cannon or culverins, which were afterwards called *arquebuse à croc* (arquebuse with a hook), in consequence of being cast with a little hook on the piece; they were placed on tripods, and used in the lower flanks, and in towers pierced with loop-holes, called murderers (*meurtrières*). Hanzelet describes it as a short fire-arm, which carried a ball of $1\frac{7}{8}$ oz., and the length of barrel 40 calibers. In our ancient statutes it is called "arquebuse," "haquebut," and "hagbut," formed of the French word *arquebuse*, which is derived from the Italian *arco*, a bow, and *bugio*, a hole, because when guns were first used, a bow was joined to the same stock that served for these fire-arms, which appear to have immediately succeeded the ancient cross-bows. The larger kind, or arquebuse à croc, required two men to carry them, and were first seen in the Imperial army of Bourbon, which drove Bonnivet out of the state of Milan. These were fired by means of the pyrites wheel-lock, which was introduced about the reign of Henry VIII., and continued in use until the

time of Charles II. It is supposed to have been of Italian origin.

The arquebusiers, or soldiers bearing arquebuses, were often armed with morions, or steel hats, called *pots;* cuirasses consisting of back and breast-plates, and *tassets*, covering the thighs. These suits are known in the Tower by the name of arquebuse armour. When hand-guns first came into use, not only balls, but steel *quarrels*, and wooden arrows, called *sprites*, were discharged from them.

Another arm, called a petrinal or poitrinal, shorter than the musket, but of larger caliber, was carried in a broad baudricke worn over the shoulder, on account of its weight, and rested on the breast when fired, whence its name; and the soldier who bore it was called a *poitrinalier*. This arm is mentioned in the relation of the siege of Rouen by Henry IV. of France, in 1592.[1]

Pistols derived their origin from Pistoia[2], a city of Etruria, where they were manufactured previous to 1544, in the reign of Francis I.; in

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[1] Grose. Father Daniel. Fabricius Colonne. Nicol's Dictionary. M. de la Noue, 18th Military Treatise. M. de Bellay. Fauchet. Monstrelet, 1400—1467. Exercise of Calivers, &c. 1608. Dr. Meyrick, vol. iii. p. 8.

[2] Anciently Pistoria.

which year the German horsemen, called *reiters*, are said to have used them in France before the French, and in the time of Henry II.; those who carried them were called *pistoliers*. These pistols were the arquebuse in miniature, the barrels being one foot in length, and fired by the wheel-lock; they were introduced into England about the middle of the sixteenth century.

The Society of Antiquarians are in possession of an inventory of the royal stores and habiliments of war in the different arsenals and garrisons belonging to the king of England in the first year of the reign of Edward VI., by which it appears, that after the invention of fire-arms, the boss and spike issuing from the centre of targets or shields was superseded by one or more short barrels fired by a match-lock, and having an aperture covered with a grating above, for the purpose of taking aim. Many of these shields are preserved in the Spanish armoury in the Tower[1]; but we learn from this inventory, that they have been falsely attributed to the troops of the Spanish Armada; and also,

[1] Or Queen Elizabeth's Armoury, Tower. These barrels load at the breech, the charge being put into an iron tube, or short barrel, which is pushed in at the end and retained there by shutting down a lid or spring.

that the word *gonne*, or gun, was applied to *pistol* barrels. Indeed, as cannons are now called guns, we may conclude that it was a general name for the barrels of all fire-arms that had not locks to distinguish them.

A sort of pistol called a dag or dagge, with a straight stock, was used about the same period as muskets and arquebuses, which, in common with others, were first fired by a match-lock, then by a wheel-lock, and afterwards by a *snaphance*[1], or flint-lock, which had a grooved *hammer* face, and a slide to cover the pan, as in the match and wheel-locks, but no *seat* to the *hammer*. Pistols were frequently introduced into the butt-end of pikes, and also, in the reign of Edward VI., in the handle of the battle-axe, the spiked club, or *holy water sprinkle*, and other weapons.

In this stage of our inquiry, it may not be improper to notice an appendage to the musketeer in the time of James[2] and Charles I.[3], called a bandalier, several of which are now in the Tower. It was a broad belt, thrown over the left shoulder, and hanging down on the right side, which not only served to support their

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[1] This appears to be merely a Dutch name for a fire lock with flint and steel.

[2] 1603. [3] 1625.

fire-arms, but had usually a dozen small boxes suspended to it by cords, each of which contained one charge of powder, together with a bag for balls. These were, however, constantly getting entangled, and several serious accidents, with loss of life, having been occasioned by the charges taking fire from the match, the bandaliers were superseded by the powder-flask and touch-box, two kinds of powder being then used, one called *corn* powder, for loading; the other, much finer, called *tutch* powder, for priming.

These innovations on the ancient military system do not seem to have been generally approved by the English, or to have produced any striking effects, since we scarcely hear any mention made of fire-arms until they occur in stat. 33. Henry VIII., when it was enacted that no hand-guns should be used of less dimensions than one yard in length, *gun and stock* included; which shows that the earliest hand-guns were much shorter than those made afterwards, and probably their caliber was in proportion, in which case they could do very little execution, considering the badness of the powder, against men in armour. The men-at-arms were so loaded with defensive clothing at this period, in consequence of the alarm created by the introduction of fire-arms, that they were rendered al-

most incapable of any offensive movement. Monsieur de la Noue says, that the ancient knights loaded themselves with anvils instead of armour, and that it was so closely fitted and sometimes screwed so firmly on, that it was almost impossible to kill them when unhorsed, although they were perfectly defenceless, as the *misericorde* or dagger, provided for such purposes, could not penetrate the joints. Philip de Comines has recorded, that at the battle of Fournouë under Charles VIII. a number of Italian knights, who were overthrown and unable to rise on account of the weight of their armour, could not be killed until they were broken up like huge lobsters, with woodcutters' axes, by the servants and followers of the army, which fully justified the observation of James I., who speaking in praise of armour said, "that it not only protected the wearer, but prevented him from doing any injury to others." In fact, we find in several battles about the time referred to, that not a single knight was slain. An anecdote in point is also related of George IV.: after the battle of Waterloo, it was proposed to make some changes in the dress of the Life Guards; the king ordered one of the soldiers to be sent for, who had greatly distinguished himself and was said to have slain six or seven French cuirassiers in single combat. He was asked a variety of ques-

tions, to each of which he assented, until the king perceiving that his opinion was biassed by the presence of royalty and his own officers, said to him, "Well, if you were going to have such another day's work as you had at Waterloo, how would you like to be dressed?" "Please your majesty," he replied, "in that case, I had rather be in my shirt sleeves;" thus demonstrating the folly of loading soldiers with useless defensive clothing, which only impedes the free exercise of their muscular powers.

Having briefly traced the various kinds of arms, and the dates when they were employed, the method by which they were fired at different periods becomes the next subject for consideration. Undoubtedly the match-lock is the most simple, being only one remove from applying the lighted match by the hand; and although it must be subject to numerous inconveniences and great uncertainty in wet weather, we find it still extensively employed in the East, which can only be accounted for from the facility of construction and consequent economy. It consists generally of a lever held back by a spring, the head of the cock or lever being split to receive the lighted match, which is retained in its place by a screw passing through the slit to tighten it on the match, and this is advanced to the powder in the pan upon pressing the trigger.

The accidents occasioned by carrying lighted matches almost in immediate contact with gunpowder, would naturally lead men possessed of any mechanical ingenuity to attempt some method of producing fire at the moment it was required; and although we now possess so many ways of effecting this object, we must not imagine that it was an easy undertaking with the limited knowledge at the disposal of our ancestors. Original inventions are frequently complicated; the fear of not having enough to effect the desired purpose, is probably the cause of beginning with too much, and we only discover after long experience, how to separate the essential from the superfluous.

The first attempt to overcome this difficulty, or at all events one of the earliest, is in the arsenal at Dresden, where there is an old büchse, with a piece of pyrites fixed opposite to the touch-hole, which requires to be rubbed with a file, chained to it, until sparks are elicited sufficient to fire the powder. This is certainly one step towards the wheel-lock. It was long known that the mineral substance called pyrites (which is a natural combination of iron and sulphur), would produce sparks by friction against steel; consequently, the first efforts were made with this substance: but, as all improvements are progressive, it would be impossible to trace them

through all their gradations until we arrive at the perfect wheel-lock, once universal in Germany and Italy, as well as common in this country, but now rarely met with except in museums. It is supposed to be of Italian origin, invented about the time of Henry VIII., and continued in use until the reign of Charles II. It consists of a small grooved steel wheel, to the axis of which a chain or swivel and powerful spring is attached: this being wound up by means of a *spanner* or key, is retained in that position by a spring-catch connected with the trigger. A piece of pyrites is firmly screwed into the *cock-head*, which, on being pulled forward, rests on the circumference of the wheel, which enters the bottom of the pan: on pulling the trigger, the wheel is disengaged, and spinning round in contact with the pyrites, it produces a stream of sparks, close to the touch-hole. These locks, however, frequently missed fire, as the pyrites being of a friable nature broke in the pan, and impeded the free action of the wheel, so that the match was usually retained to be ready for use if required. And the uncertainty appears to have been equally great with the flint-lock; for in France, as late as 1702, when the flint had wholly superseded the pyrites, and the structure differed very little from our present

musket-locks, an additional cock was attached to the end of the lock-plate, and a sliding cover placed over a hole in the *hammer-seat*, for the purpose of lighting the powder by a match if the flint failed.[1] The match was therefore, from its simplicity, preferred to all others for a considerable period, and is still used by the Chinese, Tartars, Persians, and Turks, in some provinces, either wholly or partially. The match itself was made of cotton or hemp, spun slack, and boiled in a strong solution of saltpetre, or in the lees of wine. The French have used as a slow match for cannon, willow twigs boiled in acetate or nitrate of lead, which, during its slow combustion, exhibits the re-production of metallic lead in minute globules.

Each musketeer formerly carried a tin tube, pierced full of holes, to contain the match, and prevent his being discovered, and in wet weather it was necessary to carry it in the crown of his cap, to prevent it from being extinguished.

It is said, that the steel cross-bows in use about the time of Richard III. first suggested the idea of our gun-locks, as the strings were

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[1] Glennie's Hist. of Gunnery. Walhuysen, l'Art Militaire pour l'Infanterie, p. 136. D'Etrées, Mémoire d'Artillerie. Mémoires d'Artillerie, par St. Remy (1702).

held back, and released by the action of a trigger.

The general adoption of flint-locks appears to have been about the third or fourth years of William III. (1692-3), since which time they have continued in use with little essential alteration as regards military fire-arms, although they have been constructed in a variety of forms. At the present moment, however (1840), all European nations either have adopted, or are about to adopt, the percussion system; and whatever difficulties may arise at first, it is quite certain that flint-locks will be as obsolete in a few years as the match.

It remains for me to notice one of the most important appendages to fire-arms, which in the hands of British soldiers has almost invariably produced as striking an effect as the sword and shield of the Romans did in former times, when opposed to barbarian warfare. I allude to the bayonet, the origin of which may be traced to the spiked rests of the old musketeers. But the idea of affixing a dagger to the end of the musket appears to have occurred to different officers, who occasionally put it in practice in order to convert the musket into a pike when the soldiers had exhausted their ammunition. The first bayonets were consequently merely daggers,

the handles of which fitted into the muzzles of the barrels. Father Daniel says, they were regularly introduced into France about 1671: the first corps armed with them was the regiment of fusileers raised in that year; and they derive their name from having been originally manufactured at Bayonne.

The present method of fastening them to the muzzle of the musket was also a French invention, first used by Marshal Catinat in 1693, at the battle of Marsaglia; the slaughter was immense, and the route of the allies complete. Similar success attended Marshal Tallard at the battle of Spires in 1703, and the Duc de Vendome in 1705 at Calcinata in Italy; but it was not until two great victories had been obtained by them, that they were adopted by other nations. Many other battles were almost exclusively gained by the use of them, and the Spaniards were uniformly defeated by the bayonet alone, in all their contests with the French at the close of the campaign in 1794.

Grose mentions an instance of the consternation into which a part of the British army was for a moment thrown during one of the campaigns in Flanders under William III., at seeing the French fire upon them with fixed bayonets; but they rallied, and drove the enemy out of the line.

The English grenadiers first employed them in the short reign of James II.

Bayonets however underwent several mutations before the socket bayonet was adopted: two rings were fixed to the handle to receive the muzzle, and in the reign of Queen Anne, two horse grenadiers rode before her carriage with bayonets fixed in this manner. The general introduction of the bayonet superseded the use of the pike, which was abolished in France by royal ordinance in 1703, with the advice of Marshal de Vauban; and pikes were probably laid aside in England about the same time, as in 1690 a book of the pike exercise was published by royal command, and in 1705 the Gentleman's Dictionary describes it as a weapon formerly in use, but then changed for the musket.

PART III.

ON THE MANUFACTURE OF FIRE-ARMS, AND MODERN IMPROVEMENTS.

It would be difficult, if not impossible, to ascertain all the gradations of improvement that have taken place in fire-arms since their first introduction; but they may be divided into five general classes: the first is the application of a lighted match by the hand, the second the match-lock, the third the pyrites wheel-lock, the fourth the flint-lock, and lastly the percussion-lock. In the preceding part, I briefly traced the history of the first three classes; but it is curious to remark, that although so many centuries have elapsed since the invention of gunpowder, the whole of these methods are employed in various parts of the world at the present moment, with the exception of the wheel-lock, which, although out of general use, is still frequently to be met with in Germany, and in most collections of ancient arms. Perhaps there is no branch of the mechanic arts that has so much occupied the attention of persons, unconnected with it professionally, as the improvement of fire-arms, either from its importance in a military point of view, or from the importance attached to its

perfection by all sportsmen. The consequence has been an inundation of alterations, few of which deserve the name of improvements; and they have been gradually or speedily forgotten, according to their comparative merits. One great error into which amateur improvers of fire-arms are very liable to fall, is their forgetfulness of the action of gunpowder on metals, particularly when exposed to the influence of a damp atmosphere. Many ingenious contrivances are annually produced, which, but for this circumstance, might continue to act perfectly well, and if the same mechanism were applicable to other purposes, would do credit to the inventors. Another error is that of making experiments on too diminutive a scale, and arguing that if successful with a pistol, or a musket, the same plan will prove equally efficient with a cannon: nothing can be more fallacious, or more common. As these errors arise from a want of *practical* knowledge, I merely notice them in consequence of having been so often applied to confidentially for my opinion of inventions, for which patents were about to be obtained; and I have frequently in vain attempted to convince the parties, that success was absolutely impossible; for as parents feel greater affection for their own children than for those of others, so it is with projectors and their inventions. Few persons are aware of the

immense force with which the flame rushes from the vent-hole of a large cannon, when loaded with its service charge. An experiment made a short time since at Woolwich, affords a striking illustration of this fact: a cannon ball, weighing 24 lbs., was placed exactly over the vent-hole of a loaded 32-pounder cannon, which was fired by a train of gunpowder, when the rush from the vent projected the 24-pounder ball to a very considerable height in the air, although the diameter of the hole was only two-tenths of an inch. This is one of the causes which renders the application of the percussion system to cannon more difficult than might at the first glance be imagined; and in order to prove the necessity of making all experiments in gunnery on as large a scale as it is ever intended to apply to the same principle, I will illustrate it by a failure of my own. Conceiving that this difficulty would be overcome if the cock struck round the vent-hole, leaving a large conical space in the centre for the escape of the flame, I constructed a cannon-lock on this principle, which was tried on board the "Excellent" at Portsmouth, and found to succeed perfectly with 12-pounders, and even with 24-pounders not shotted; but when fully charged, the lock was broken. I have since constructed a very cheap and simple one, which answers perfectly. Before entering upon the

manufacture of fire-arms, I will enumerate the various plans now adopted in England, as well as a few that have become obsolete; but it would be as unprofitable as uninteresting to enter into a detail of the "thousand and one" failures, to which the introduction of fulminating powder has given birth. With respect to military fire-arms, very little alteration has been made within the last century, flint-locks being still in use: the immense stock in our depôts and arsenals prevents the immediate adoption of many improvements that have been suggested, and to furnish part of our army with one plan, and part with another, might create as much jealousy as inconvenience; but in the event of a war, the percussion system would soon become universal, the government having decided on the adoption of the copper cap, and already delivered out new percussion muskets to several regiments.

Every one has seen a musket, and the principle of the flint-lock is almost too familiar to require description. I would merely observe, that the only difference between a flint-lock as applied to a musket, or to a fowling-piece, consists in the superior workmanship of the latter. The mere varieties of form which the flint-lock has undergone are unworthy of notice, when speaking of it as a *principle*, now entirely abandoned for sporting purposes, except by a very

few old gentlemen of the old school. One of the most important changes ever effected in fire-arms, is the application of detonating or fulminating powder. Various compositions of this kind have long been known to chemists, but no one appears to have thought of applying them to the purpose of igniting gunpowder previous to the Rev. Mr. Forsyth, who obtained a patent in 1807.[1] Some of these compositions are not adapted to the purpose, either from their expense, or from the danger of using them, such as fulminating gold, silver, and platinum: but fulminating mercury is well adapted for the purpose, although, when uncombined with other inflammable substances, it is very uncertain in its action on gunpowder. The French commissioners appointed by the government to investigate its properties, have decided that the best proportions are ten parts of the fulminate of mercury with six of pulverine or meal gunpowder; therefore, all the French copper caps are primed with this composition, although Dr. Ure states, that he has analysed the powder taken from some French caps which fired extremely well, consisting of equal parts of *bad* fulminate of mercury and the ingredients of gun-

[1] Date of patent, April 11. 1807.

powder. Chlorate of potash and sulphuret of antimony in equal proportions form a fulminating powder still in use for cannon tubes. Chlorate of potash, with sulphur and charcoal, is the composition that was first introduced by Forsyth, and although it is much more corrosive than the mercurial powder, it produces a much stronger fire.[1] The mechanical means by which these powders have been applied to fire-arms remain to be described. The original patent was first produced with a magazine turning on a roller or tube screwed into the breeching of the gun: a small portion of the fulminating powder being deposited in the roller, the magazine was restored to its firing position, and the cock struck on a pin with a spiral spring attached to it, which inflamed the gunpowder. This arrangement had a clumsy appearance, and required to be nicely adjusted and kept clean, otherwise it was liable to set fast; but the original inventor does not appear to have made any improvement during the whole term of his patent. The first alteration was made by one of his workmen, who invented a self-acting maga-

[1] Chlorate of potash, 5 parts; sulphur, 2; and charcoal, 1; combined with from one-third to one-fourth of its weight of fulminate of mercury, form a very strong and certain fulminating powder.

zine sliding along a bar by means of a lever attached to the cock; but having kept it a secret from his employers he was discharged, and entered the service of Mr. Beckwith, who soon produced it; but was immediately stopped by the patentee, who was enabled to avail himself of all improvements, and to prevent others from interfering with him, as his patent was not for any particular mechanical means, but for a *new principle:* accordingly, he adopted this alteration principally for pistols, as it was more exposed to wet than the original plan. Another workman caused the magazine to revolve by the action of the cock, which was partially adopted for a short time; but towards the expiration of the patent, almost every gunmaker had infringed, and a general compromise or license was effected, so that it became thrown open to the trade, and every maker had some plan of his own. Joseph Manton produced a steel plug or pin fitting into the cock-head, with fulminating powder behind it, which was extremely neat in appearance, but soon got out of use from the trouble of keeping it clean: he afterwards invented the copper tube, which still has many admirers.

Joseph Manton also patented a small conical plug of wood, with a short wire in the centre, and pellat of fulminating powder at the end; but

this plan is liable to several objections, or I should have introduced it two years previously having employed precisely the same arrangement for some experiments with great guns at Woolwich in 1832. Small paper patches containing a pellat of fulminating powder, were at one time much in vogue: these were either pressed into the front of the cock and struck upon a peg or *nipple*, screwed into the breeching, or were carried in steel plugs separately, to be put into the cock-head, and removed each time the gun was fired? Sometimes they were arranged round the circumference of a small wheel attached to the cock, so as to require turning one notch to bring them successively forward, and thus save the trouble of putting a patch or plug in each time. The late Mr. Joseph Egg has had several ingenious contrivances for self-primers with small balls of fulminating powder, which are brought forward in succession by the action of the lock: such plans will act very well, provided sufficient care be taken to keep them clean, and the workmanship be excellent; but the extreme simplicity of the copper cap has so completely obtained the suffrages of the majority of sportsmen, that nine-tenths of the fowling-pieces now made are certainly on that construction. It becomes,

therefore, an interesting inquiry, to ascertain who really was the inventor.

The late Mr. Joseph Egg and several other persons lay claim to it; but I have taken some pains to ascertain the truth, and if in error, shall be obliged by better information on this or on any other subject. Mr. Egg, I believe, purchased it from Mr. Roantree, a gun-maker at Barnard Castle, Durham, who had it from a workman employed by Mr. Joshua Shaw, now residing at Philadelphia.[1] I can trace it no further. Mr. Shaw assured me that in 1814 he invented a steel cap, which, when fired, was retained to be primed again; that in 1815 he made a pewter cap, which was thrown away after using; and lastly, that in 1816 he used a copper cap precisely similar to those at present employed. He made application for a patent in England, but the solicitor to whom it was referred, decided that it could not be obtained without infringing Forsyth's patent then in force. Baron Heurtloup has patented a very novel and ingenious method of firing guns by percussion, which has never yet come into use from a variety of causes, and it is probable that it may never be adopted; but it deserves notice, as being

[1] Mr. Shaw, although residing in America, is an Englishman, and by profession a landscape painter.

quite original. He has named it the *koptipter*, from its peculiar action of *cutting and striking:* it is dependent on the fact, that when fulminating powder is inclosed in a tube of soft metal, it may be cut through by a sharp-edged instrument without explosion, although when struck by a blunter edge it will ignite. On this principle the baron has contrived a long and very thin tube of soft metal filled with fulminating powder, which is inclosed in the stock, and gradually advanced by the action of the lock, which causes a small portion of the tube to protrude just over the touch-hole: the cock in falling first cuts off this projecting portion with a sharp edge, and instantly strikes the piece thus detached with a lower blunt elevation on its striking surface, which explodes it simultaneously with the first operation.

The simplicity of the copper cap, however, almost precludes the adoption of any complicated plan, although ingenious. The most simple mechanical arrangement for firing by percussion (that I am aware of), is the lock invented by myself, and patented in 1839: it consists of only five principal parts, including the guard, trigger-plate, and trigger: it fires on the under side by means of a copper cap, and has the shortest and most direct communication into the barrel that is possible, being in a right line: the stock is much

stronger, and the cost considerably less than any other plan. Two muskets fitted with my locks were sent to Woolwich by order of the Master-general of the Ordnance in July, 1840, and fired 2000 times with ball cartridges, without a single failure or any mishap whatever. Sometimes 100 rounds a day were fired without cleaning; after which they were tried against time, and were fired equally quick with the new percussion muskets: these great advantages being fully established, it is probable that at some future period, if not immediately, they will be adopted. The emperor of Russia has honoured me with a splendid diamond ring as a mark of his Imperial majesty's approbation of this invention, and referred the musket sent, to the minister of war. It is my wish to avoid egotism as much as possible; but in justice to my readers as well as to myself, I cannot omit one link in the chain of improvement, merely because it relates to my own inventions.

As the perfect ignition of the gunpowder is influenced by the form of the breeching, it may be proper to notice the most essential alterations that have occurred. The first great improvement was made by my grandfather, the late Henry Nock [1], whose patent breeching produced

[1] Patent, dated April 25. 1787.

an important change in fowling-pieces. Previous to his invention, the breeching or plug of a gun was exactly similar to what the plug of a musket-barrel now is; namely, a solid lump of iron screwed into the barrel to close one end, and the touch-hole was drilled through the side of the barrel above it. These guns fired very slowly, and a considerable portion of the powder was blown out uninflamed; consequently much of the force was lost. The patent breeching caused the powder to be ignited in the centre, and prevented the barrel from becoming partially foul: it was much safer, and not liable to leak by long-continued use, and greatly improved the strength and regularity of the shooting. These advantages, being fully established, ensured the immediate adoption of the plan, by all gun-makers, when his patent expired upwards of fifty years ago, and no real improvement has been made on it for flint guns since: but when percussion guns came into general use, a complaint [1] was made that they did not shoot so strong as the old flint guns; which, to a certain extent was true, as the flame from the percussion powder passed through the charge with too much rapidity and actually lifted it in the barrel by its own force, with-

[1] Colonel Hawker.

out inflaming the whole of the powder. I made many experiments on the subject, and having ascertained that the flame of all fulminating powders will pass through the centre of a box filled with gunpowder, without igniting one grain of it, I conceived that by giving greater resistance to the passage of the flame, the whole of the gunpowder would be exploded; and this I found on experiment to be the case. I have consequently ever since made the interior of the breeching of an elliptical form, which I find increases the strength of the shooting considerably.[1] As the fact of fire passing through fine dry gunpowder without inflaming it, might have been doubted by many, I constructed a simple apparatus in illustration, which has been shown to hundreds of persons publicly and privately. This is sufficient to prove that gunpowder is not quite so easily inflamed as might be imagined, and that the ignition depends on the velocity with which the flame is transmitted; for gunpowder, like all other inflammable substances, requires to be raised to a certain temperature before it will ignite, namely, to a dull red heat, or about 600° Fahrenheit. If the temperature be below that

[1] Similar to the *chambre à poire* of the French, applied to cannon 150 years ago, but objectionable, as a cannon cannot be washed out like a fowling-piece barrel.

point a few degrees, the powder may be decomposed by the partial inflammation of the sulphur, without any explosion taking place; or if the heat be sufficient, but pass with such rapidity through the powder, as not to raise the grains to the necessary temperature, then the same effect will ensue, though from a different cause; velocity of transit producing similar results in the latter instance, to that produced by deficiency of heat in the former—so that it might be possible to calculate, theoretically, the velocity that must be given to a red-hot ball to enable it to pass through a barrel of gunpowder without causing explosion. The passage of the electrical fluid through gunpowder may be adduced in evidence of the ignition being dependent on the degree of velocity; for, if the charge of an electrical jar, or battery, be transmitted through good conductors, such as metallic wires, it will not inflame unconfined gunpowder; but if a tube of water, or some other fluid, or merely a piece of wet string form a part of the circuit, the velocity is diminished by the inferior conducting power, and the gunpowder will invariably explode, *time* being required to light gunpowder, as well as to perform every other operation. The patent breeching, or some external resemblance of it, is now used for all fowling-pieces, except for those of the commonest description,

and it possesses other advantages beyond its internal structure; for, being case-hardened, it resists the action of rust much longer, and is not so easily injured, as soft iron.

Joseph Manton contracted the patent breeching externally, in order to bring the locks closer together; but, in so doing, he lengthened the hole down the centre considerably, and no advantage was gained in quickness of ignition: he was, however, copied by most gun-makers.

I will now proceed to explain such parts of the manufacture of fire-arms as I conceive most likely to be interesting. The stocks of all military fire-arms are made of walnut-tree, and by far the greater number of fowling-pieces: it is the toughest and best wood for the purpose; but maple and ash have been introduced for sporting guns, and, when properly selected and well seasoned, they are extremely strong and beautiful; but they are more expensive to work, and being of a light colour require to be stained in order to bring out the natural veins of the wood and to make them darker. All gun-stocks are coloured with cold drawn linseed oil and alkanet root: the best, when sufficiently dry, are polished and then varnished with a solution of shell lac in good spirits of wine, which should not be used like French polish, but applied with a piece of rag, and, when dry, rubbed down with fine

pumice powder, and varnished again and again until all the pores of the wood are filled, and finally polished up with oil and rotten-stone by the hand. The manufacture of this branch requires little observation, as good workmen alone are requisite to execute the various parts; but as the success of shooting flying depends very much on a proper adjustment of the stock to the stature of the shooter, or to habits he may have acquired, it may be considered as a general rule, that the taller any man is, the longer and more crooked ought to be his stock. There is, however, one important point, not sufficiently attended to by gun-makers or generally known to sportsmen, which is technically called *throwing off*, that is, giving to the stock an inclination outwards to allow for the swell of the chest, as the eye cannot without difficulty be placed correctly in a line with the centre of the shoulder; consequently nine persons out of ten when they miss (supposing the crook and length to be suitable) shoot to the left of the object aimed at, particularly if the centre of the stock be in a right line with the barrel, or, as is not unfrequently the case, be *thrown off* the wrong way. It follows, therefore, that the broader the chest, the more ought the stock to be inclined or bent outwards sideways; and the extent to which this may be required, is easily ascertained by ob-

serving the line of the barrel when the gun is thrown up to the shoulder at any distant fixed object.

Machinery for the stocking of military guns has been proposed and adopted to a considerable extent in France and in America; the barrel, lock, and furniture being entirely let into the wood by this means: but one inconvenience has arisen in the difficulty of filing the iron or brass work so accurately as to fit the wood thus prepared. Every difficulty of this kind is, however, entirely obviated by my patent lock, which from its simplicity at once renders the adoption of machinery both practical and economical. The locks of guns have undergone so many mutations that it would be useless to enumerate them; the marked changes of principle have already been noticed in a description of the manufacture of them may be comprised in few words — *good filing and fitting with excellent tools.*

In every mechanical business depending almost wholly on manual labour, perfection of workmanship can rarely be obtained otherwise than by dividing it into various branches: each workman, being confined to one department only, acquires a degree of excellence unattainable by one whose occupations are various: this circumstance renders it impossible for any coun-

try gun-maker to finish his work to the same extent of perfection as a first-rate London maker.

Every best finished gun usually passes through fifteen or sixteen hands, each of which constitutes almost a distinct trade; although two or three branches are often combined, or sub-divided, according to the extent of business. They may be arranged in the following order:—

1. Barrel forger; 2. lock and furniture forger; 3. barrel borer and filer; 4. lock filer; 5. furniture filer; 6. ribber and breecher; 7. stocker; 8. screwer-together; [illegible]ator; 10. maker-off; 11. stripper an[illegible] 12. lock finisher; 13. polisher and ha[illegible] 14. engraver; 15. browner; 16. stock [illegible] The barrel making being also divided i[illegible] branches.

The forging of [illegible]s is an operation requiring more particula[illegible]cription, and varying according to the quality intended to be produced, or the use to which the barrels are to be applied.

The first process in the manufacture of musket or common barrels is the making what are technically called *skelps*. The skelp is a piece of iron about three feet long and four inches wide, but thicker and broader at one end than at the other: and the barrel of a musket is formed by forging out such pieces to the proper dimen-

sions, and then folding or bending them round into a cylindrical form until the edges overlap, so that they can be welded together. Professor Babbage, in his interesting work on the "Economy of Manufactures[1]," has given two cases of combination among workmen in this branch so much to the point, that I will repeat them in his own words, having seen the machinery to which he alludes. "About twenty years ago, the workmen employed at a very extensive factory in forging these skelps out of bar-iron, 'struck' for an advance of wages; and as their demands were very reasonable, they were not immediately complied with. In the mean time, the superintendant of the establishment directed his attention to the machinery, and it occurred to him that if the circumference of the rollers, between which the iron was rolled, were to be made equal to the length of a skelp, or of a musket-barrel, and if also the grooves in which the iron was compressed, instead of being equally deep and wide, were cut gradually deeper and wider from a point in the rollers until it returned to the same point, then the bar-iron passing between such rollers, instead of being uniform in width and thickness, would have the form of a skelp. On making the trial, it was

[1] Economy of Machinery and Manufactures, p. 245. 1st edit.

found to succeed perfectly; a great reduction of human labour was effected by the process, and the workmen who had acquired peculiar skill in performing it ceased to derive any advantage from their dexterity."

Another remarkable instance of the effect of combination among workmen occurred a few years since, which led to the completion of the barrel by machinery.

"The process of welding the '*skelps*' (as formed by the method just described), so as to convert them into gun-barrels, required much skill; and after the [illegible] of the war, the demand for muskets [illegible] greatly diminished, the number of perso[illegible]ed in that line was greatly reduced. T[illegible]stance rendered a combination easy: a[illegible]e occasion, when a contract had been [illegible] for a considerable supply to be delivered o[illegible]ed day, the men all struck for such an advance of wages as would have caused the completion of the contract to be attended with a very heavy loss. In this difficulty, the contractors resorted to a mode of welding gun-barrels, according to a plan for which a patent had been taken out by them, some years previous to this event. It had not then succeeded so well as to come into general use, in consequence of the cheapness of the usual mode of welding by hand-labour, combined with some

other difficulties which the patentee had to encounter: but the stimulus produced by the combination of the workmen induced him to make new trials, and he was enabled to introduce such a facility in welding gun-barrels by rollers, and such perfection in the work itself, that in all probability few, if any, will in future be welded by hand-labour. The process consisted in turning a bar of iron, about a foot long, into the form of a cylinder, with the edges a little overlapping. It was then placed in a furnace, raised to a welding heat, and taken out, when a triblet or cylinder being placed in it, it was passed quickly through a pair of rollers. The effect of this was that the welding was performed at a single heat, and the remainder of the elongation for bringing it to the length of a musket was performed in a similar manner, but at a lower temperature. The workmen who had combined were of course no longer wanted, and, instead of benefiting themselves, they were reduced permanently, by this improvement in the art, to a considerably lower rate of wages: for as the process to which they had been habituated, required peculiar skill and considerable experience, they had hitherto been in the habit of earning much higher wages than other workmen of their class. On the other hand, the new method of welding was far less

injurious to the texture of the iron, which was now exposed only once, instead of three or four times to the welding-heat, so that the public derived advantage from the superiority as well as from the economy of the process. Another advantage has also arisen from its introduction: for the new process is applied to the manufacture of iron tubes, which can thus be made at a price which renders their employment very general. They are now to be found in the shops of all our larger ironmongers, in various lengths, with screws cut at each end; and are in constant use for t[illegible]vance of gas for lighting, or of water [illegible]g our houses."

The barrels for f[illegible]es are of various kinds, as *stub*, *stub-t*[illegible]*wist*, and *Damascus-twist*, and some [illegible]nbination of the two latter ones, as [illegible]other description called *stub-Damascus*. [illegible] are the best varieties, but a number of inferior kinds are made, which do not deserve notice, and are only employed for very common guns. I will now explain the method of producing all the varieties above named.

In order to make *stub*-iron, old horse-shoe nails, called *stubs*, are collected, then packed closely together, and bound with an iron hoop, so as to form a ball about ten or twelve inches in circumference; which, being put into a fur-

nace or forge-fire, and raised to a welding heat, is united by hammering, and drawn out into bars of convenient lengths, for the purposes intended. This method is adopted for the locks, furniture, and breechings of all best guns, and is to a certaint extent practised for barrels, though not so much as formerly, more expeditious methods being employed on a large scale; and the quantity that can be obtained in this country being not only inadequate to the demand, but inferior in quality, immense numbers of horse-shoe nails are imported from France, Holland, Sweden, and other parts of the continent, in casks containing from [illegible] cwt. each. The most approved mode [illegible] of converting them into gun-barrels [illegible] sorting and picking them, to separate [illegible] cast-iron or impurities are mixed with [illegible] to put about half a hundred weight [illegible] large cast-iron drum or cylinder, crossed internally with iron bars, through the centre of which a shaft passes, which is connected by a strap with the steam-engine, and the revolution of the drum actually polishes the nails by their friction against each other; they are then sifted, by which every particle of dust is removed. The steel intended to be mixed with them is clipped by means of large shears, worked by the engine into small pieces, corresponding in size to the stubs, and afterwards cleansed by

a similar process. About 40 lbs. are thrown on to the inclined hearth of an air-furnace, where they are *puddled* or mixed together with a long iron rod, and withdrawn in a mass called a *bloom*, almost in a state of fusion, to be welded under a hammer of three tons weight, by which it is formed into a long square block: this being put in, at another door of the same air-furnace, is raised to a bright red heat, and drawn out under a tilt hammer of a ton and a half weight, into bars of a proper size to pass the rollers, by means of which it is [illegible]d to rods of the required size. The a[illegible]having two doors prevents any loss of [illegible]he moment one ball of stubs is withd[illegible]her charge is put in, and the two oper[illegible]n together, keeping both hammers [illegible] The iron thus produced is very tou[illegible]e from specks or greys, but stubs are har[illegible]ver used alone, as they were formerly, being too soft; therefore, a portion of steel is mixed with them, which varies from one-eighth to one-half of the whole mass. It need hardly be remarked, that the advantage to be derived from the use of horse-shoe nails does not arise from any virtue in the horse's hoof, as some have imagined, but simply because good iron is, or ought to be, originally employed for the purpose, otherwise the nails will not drive into the hoof; and the iron, being worked

much more, is freed from its impurities, which can only be effected by repeated workings.

When gun-barrels are manufactured from stub-iron by a process similar to that of musket barrels, they merely exhibit a mottled appearance on the application of acids. It is also usual to make what are called *stub* barrels from *scrap* iron cut into small pieces by means of shears worked by the engine. It would be difficult to define what scrap iron is, or what it is not, being composed of every thing in iron that has previously been manufactured, as well as of the cuttings from the various manufactories. These are sorted and employed in preparations of various qualities, known by the names of fine-twist, *Damascus*-twist, *stub*-twist, common iron, *threepenny skelp* iron, *twopenny* or *ninepenny skelp*, *Sham-damn skelp*, &c. I have been surprised, on looking over cart-loads of the apparent rubbish, that I could hardly find two things of a sort, excepting the cuttings and punchings of sheet-iron, which abound, from the variety of articles manufactured of that material. The object of preparing iron from small pieces, is to cross and interweave the fibres in every possible direction, and thus greatly to increase its tenacity. Very few *plain stub* barrels are now made, as iron of inferior quality, when *twisted*, finds a more ready sale in the Birmingham market than good old-

fashioned *stubs*, which are nearly extinct, in consequence of the mania for cheapness in every branch of manufacture. For the finest description of barrels, a certain proportion of scrap steel, such as broken coach-springs, is cut into pieces and mixed with the iron by the operation called *puddling*, by which the steel loses a considerable portion of its carbon, and becomes converted into *mild* steel, uniting readily with the iron, and greatly increasing the variegation and beauty of the twist. In whatever manner the *iron* may be prepared, the operation of drawing it out into [illegible] or twisting is the same. This is effected by passing the bars, while red hot, between [illegible]s until extended several yards in length, half an inch wide, and varying in thickness according to whichever part of the barrel [illegible] intended to form: these ribands are cut into convenient lengths, each being sufficient to form one-third of a barrel: one of these pieces is made red hot and twisted into a spiral form, by placing one end in the prong of an iron rod, which passes through a frame, and is turned by a handle, the riband being prevented from going round without twisting by means of an iron bar placed parallel to the revolving rod. The spiral thus formed is raised to a welding heat, and dropped on to a cylindrical iron rod, which being struck forcibly

on the ground (called *jumping*) the edges of the spiral unite, and the welding is then completed by hammering on the anvil: the other spirals are added according to the length of the barrel, and the forging is finished by hammering regularly all over. The ends of each spiral should be turned up and united at each junction of the spirals, to avoid the confusion in the twist occasioned by merely dropping one spiral on another; but this is rarely done. Wire-twist, of any degree of fineness, may be obtained by welding alternate laminæ of iron and steel, or other qualities, together; the compound bar formed is drawn into ribands, and twisted in the same manner as the preceding. The effect of twisting the iron not only increases the strength of the barrel, but adds considerably to its strength by opposing the longitudinal direction of the fibres to the expansion that takes place in the act of firing. The iron called *Damascus*, from its resemblance to the celebrated Oriental barrels and sword-blades, is now manufactured in great perfection in this country, as well as in France and Germany, and may be varied in fineness or pattern to almost any extent, according to the various manipulations it may undergo. One method is to unite, by welding, 25 bars of iron and *mild steel* alternately, each about 2 feet long, 2 inches

wide, and $\frac{1}{4}$ of an inch thick; and having drawn the whole mass into a long bar, or rod, $\frac{3}{8}$ of an inch square, it is then cut into proper lengths of from five to six feet; one of these pieces being made red hot is held firmly in a vice, or in a square hole, to prevent it from turning, while the other end is twisted by a *brace*, or by machinery, taking care that the turns are regular, and holding those parts which turn closer than others with a pair of tongs; the rod is by this means shortened to half its original length, and made quite round. If only two pieces are employed to form the ri is turned to the right, and the othe ft; these being laid parallel to each nited by welding and then flattened; square rods are used, the centre o d in a contrary direction to the ou nd this produces the handsomest figur se operations the alternations of iron and steel change places at every half revolution of the square rod composed of twenty-five laminæ; the external layers winding round the interior ones, thus forming when flattened into a riband, irregular concentric ovals or circles. The fineness of the Damascus depends on the number and thickness of the alternations; and the figure of the riband when brought out by acids resembles that of a curled ostrich feather; but when wound into a spiral form, and

united on its edges by *jumping*, the edges bend round and the figure is completed. The French Damascus is usually finer than ours, and they sometimes veneer it on common iron; but this is constantly done in Birmingham, where every species of deception is practised on a large scale, and they often wind a thin riband of Damascus, or superior iron, round iron of the worst quality; even gas tubing is considered good enough, when coated in this manner, to form gun-barrels of a very low price with a high-priced appearance. Stub Damascus is merely one square rod of Damascus iron twisted and flattened into the riband for forming the barrel.

Damascus and [illegible] is a riband of each, twisted together [illegible] greater variety; but there is no quality [illegible] as the best regular *stub-twist*. The [illegible] iron, known by the mark C C N D, [illegible] springs, form an excellent combination for Damascus barrels. The next operation to forging is rough boring; this is usually performed by machinery. A long square *bit*, attached to a rod, revolves with great rapidity, while the barrel is pressed forward by a crooked lever, one end of which the workman holds, and passes the other end along a series of nails or pegs, driven into the top edge of the trough or bench, on which the barrel is placed, thus forcing the barrel forward along the boring

bit. Water is kept constantly flowing over the barrel during the process, otherwise the heat generated by the friction would soon soften the bit, and render it useless. The outsides are then ground on very broad stones turned by the engine; the workman sits on a kind of wooden horse, firmly chained to the floor; a sloping board, nearly in contact with the grindstone, is placed before him, against which he leans, and rests the barrel; a long iron rod passes through the barrel, and projects at each end, sufficiently to form handles, and at the same time an axis, on which the barrel [illegible] re or less freely, according to the deg[illegible]sure against the board. By moving [illegible]y sideways, the whole surface is grou[illegible]nd although the stones are amply sup[illegible]vater, the sparks are elicited from th[illegible]ent of surface in such abundance as t[illegible]ole brilliant fire-works. It is evidently impossible to finish barrels with any great accuracy on a grindstone, though most of the barrels that are made into guns in Birmingham are merely smoothed up after this process—an appearance of regularity being given to them at the muzzle by filing; but if transverse sections were made at different distances, they would be found very unequal in substance, as is always the case with musket and other common barrels, although some of the

grinders are able to finish with considerable accuracy. It is in the ground and rough-bored state that most of the best barrels are sent to London, where, after being set perfectly straight, they are fixed on a movable carriage, which is drawn gradually forward along a level surface or railway, by means of a weight and pullies; the boring bit being fixed in a square hole in the axis of a fly-wheel which is turned by hand or by machinery, while the barrel slowly advances until the bit passes out at the opposite end to that at which it entered. The same square bit is made to enlarge the bore to the required size by the insertion of a *spill*, which is simply a long piece of wood slightly taper, flat on one side and round on the other: the bit being fixed along one side of the bit causes it to cut triangles only, and the size of the calibre may be very gradually increased by the interposition of strips of writing-paper between the *spill* and the bit. A similar method is adopted in Birmingham, only a greater number of barrels are fine bored at the same time and by steam machinery. After the barrel is correctly bored, the external part is turned in a lathe; a steel mandril is introduced at each end, and the superfluous metal is taken off either by hand or by a sliding rest, the latter being of course by far the best method. The barrel is

thus rendered perfectly correct and equal in every part, wherein consists the great difference between town and country work. The barrel being *tapped*, that is, screwed at the breech end, and the plug fitted, is now proved (according to a scale fixed by act of parliament) with a charge of powder proportioned to the weight of a leaden ball that fits the bore; this is always five or six times the ordinary load; besides which it is forced with water; as minute defects, invisible to the eye and not affected by the proving, are thus easily detected. When *false-breeched*, *ribbed*, *stocked*, and *screwed-*[illegible]*he* barrel is bored for shooting, and s[illegible]*outside*. Double barrels have a flat st[illegible] the inner side of each, previous to la[illegible] toge her; about four inches of the b[illegible]s bra zed, or hard soldered, and the [illegible]f the length *soft* soldered; the upper [illegible]der ribs being soldered on at the same time. The practice of *braizing* the barrels is decidedly injurious, by softening that part more than the other; but if they were only soft soldered the inconvenience would be far greater, as the barrels would be liable to come asunder by the repeated expansion and contraction that take place in firing, as well as by the force required to turn out the breechings.

The progressive stages of best gun-making

may be briefly enumerated in the following order, supposing the lock and barrel to be already made. The lock and barrel being jointed to each other (if the plan require it), are given to the stocker, who lets them into the wood, which ought to have been previously cut out of the plank at least two or three years, in order to be perfectly seasoned. It is the stocker's business to attend to the bend and throwing off, and there is no branch of the business better paid for. A best stocker in full employment can earn four pounds a week, and by great exertions has been known to earn more. The next workman is the screwer-together, who lets in all the furniture and [illegible] the screws: when this is done, the [illegible] by another man who fits the [illegible] finishes the external part of the breech. The barrel then goes to the barrel-maker [illegible] and bore for shooting, and the gun is returned to the screwer-together, or to another workman to *make off* and chequer, that is, to smooth and finish the woodwork. From him it passes to the *stripper* and *finisher*, who takes the whole to pieces and corrects any trifling errors of preceding workmen. The barrel is engraved and goes into brown; an operation performed by producing successive coatings of rust on the surface, and brushing them off as they arise with a fine steel wire *scratch*

brush, until the required colour be obtained, which usually takes a week, and is effected by a solution of metallic salts, combined with nitric ether [1]; during this process the lock and furniture are polished, engraved, blued and hardened, and the stock is oiled and polished. The hardening is performed by stratifying the various parts in an iron pan, with animal charcoal, prepared from bone and ivory dust, or old shoes: the whole is then exposed to a full red heat for about an hour, or according to the size of the work, the pan is withdrawn from the fire, and the contents thrown into a bucket of water. The rationale of this operation is that the surface of the iron becomes converted into steel by the absorption of the carbon, and the beautiful colours are produced by the *animal matter remaining in it*, the variety of the colour being also affected by the quality of the iron. The whole of the parts now return to the finisher, and the gun is completed. There is an affectation of mystery in the operation of boring for

[1] The following recipe is perhaps as good as any, to which add three pints of boiling water: the sulphate of copper should be first dissolved in the water, and the other ingredients previously mixed together added: — Nitric ether, 6 oz.; alcohol, 1 oz.; sulphate of copper, 1½ oz.; muriated tincture of iron, 1½ oz.; tincture of gum benzoin, 1½ oz.

shooting; every maker having some fancy of his own; but the best and most usual form, for the inside of a barrel, intended to throw shot, is a cylinder slightly relieved, or enlarged a few inches at the breech end; long barrels for duck-shooting should be eased gradually towards the muzzle end also. It is evident that a barrel much opened behind must recoil more and *lead* sooner, than one approaching nearer to a cylinder; and if resistance be necessary, it should be given to the powder, and not to the shot, which is accomplished by the elliptical form of breeching already mentioned. It may not be improper in this place to [illegible] the greater part of the preceding pa[illegible]rated by numerous specimens and e[illegible] was read by me in the form of lectu[illegible]oyal Institution and Society of Arts [illegible]d written the year previous: but in the [illegible]book was published, called "The Gun," containing information respecting the *manufacture of fire-arms* only. The author, Mr. Greener, has since assured me, that he was not aware when he published his book that any one had ever preceded him on the same subject. I shall conclude with some observations on rifles; but I would previously remark, that the condensation of air as a means of generating heat sufficient to ignite gunpowder was applied to guns by Monsieur Pauly, but

failed in consequence of the great difficulty of keeping it in order.

The application of condensed air as a projectile force, has long been familiar in the air-gun: and high-pressure steam is daily exhibited at the Gallery of Practical Science, in London, feebly performing the office of gunpowder.

PART IV.

ON RIFLES, BALLS, SHELLS, WADDING, ETC.

RIFLED barrels are only used for throwing balls; they are always much thicker and heavier than barrels intended for shot, in order to render the aim more steady, as well as to admit of cutting the grooves with safety. Rifling consists in cutting any number of grooves in a spiral direction down the inside of the barrel, usually from seven to fifteen, dividing the bore or surface into *lands* and *furrows*, the grooves being called the *furrows*, and the surface left, the *lands*. In order to diminish friction, as well as to impress the ball more forcibly, the lands ought to be narrower than the furrows. The object of rifling is to give to the ball a rotation coincident with the line of its flight, and thus to correct the variable rotation which every ball, passing freely along a smooth bored barrel, receives from its friction against the sides. The latter rotation never can coincide with the axis of the barrel, but must have a tendency to deflect the ball from the line of aim, according to the last impulse it may receive on quitting the barrel. Rifling also corrects any inequality in the density

of the ball itself, by causing it to present alternately every part of its surface in its passage through the air, from which it is evident that straight grooves can be of no use whatever, as they cannot communicate rotation to the ball.

The effect of the variable rotation produced by a smooth bore when the ball moves freely in it, may be illustrated by an experiment made by Mr. Robins[1], who, in 1742, wrote the first rational work on gunnery that was ever published in this country, which laid the foundation for all the very accurate and long-continued experiments made by Dr. [2], and [illegible] about forty years afterwards.[3] A perf[illegible]ght and correctly bored smooth barre[illegible]l on a heavy carriage and levelled a[illegible]60 yards distant; the deflection was [illegible]ad so varied, that the ball sometimes [illegible]ards to the right or to the left, and ofte[illegible]rt, by striking the ground 200 yards nearer than at other times.[4]

It is also a remarkable fact, that a barrel bent to the right or to the left will at very long ranges throw the ball in a contrary direction to its curvature: thus, for example, a barrel bent to the right will throw the ball to the right, at 100 or 200

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[1] Robins on Gunnery, p. 328—341.

[2] Dr. Hutton's Tracts, vols. ii. iii.

[3] 1785 to 1792.

[4] Robins, p. 150.

yards; but at 600 yards it will actually cross the line of aim and fly many yards *to the left* of the target. In order to comprehend the latter experiment, it is only necessary to reflect, that a ball passing along a tube bent to the right and impelled straight forward by the action of the powder, must necessarily move along the left side and receive a rotation caused by its friction from right to left. Immediately on leaving the barrel, the direction of the ball is influenced by the curvature given, and therefore proceeds at first towards the right; but this influence soon ceases to operate, while the rotation from right to left communicated to the ball continues in force; therefore it will gradually wind itself across the line of aim, at a distance of five or six hundred yards will pass to the left, or always in an opposite direction to the curve of the barrel.

The usual method of rifling a barrel is by means of a long square bar, or rod of steel, which is twisted to the required degree of curvature, and then accurately ground with oil and emery in square holes, so as to render every portion of its length precisely equal in curvature, which operation requires considerable care and time. There are generally several rods of this kind to each rifling bench, of different curves, so as to vary from three fourths of a turn, to a turn and

a half, in three feet; but should any other curve be required for experimental purposes, a new rod must be made for each, which becomes expensive.

A rod of this description is correctly fitted into square holes, in two *puppets*, or heads, similar to those of a lathe, through which it can be freely drawn backward and forward by means of a cross handle, turning on its centre, to which is attached a dividing plate to regulate the cuts or grooves. The barrel being bored perfectly true, is fixed to the end of a long bench opposite to, and in a direct line with, the rifling rod at the other end. A piece of wood is turned to fit the barrel, in which a longitudinal groove is sunk to receive the cutter, which is made of tempered steel, and has ten or twelve sloping teeth in it. The piece of wood screws on to the [illegible] by means of an iron ferrule; and at the commencement, the teeth of the cutter only project very slightly beyond the surface of the wood. The cylinder of wood being entered into the barrel, the rifling rod is pushed forward, and the projecting teeth of the cutter make a faint groove in a spiral direction down the inside of the barrel: the rod is worked backward and forward, until the teeth cease to cut, when the wood is withdrawn, and the rod turned an equal division of a circle by means of

the dividing plate, according to the number of grooves intended to be made: it is again entered, and another faint groove cut, and so on, until all the grooves are sunk to the same depth as the first. The wood is again withdrawn, and the cutter elevated a little, by taking it out of the groove in the wood, and placing underneath one or two slips of writing-paper soaked in oil; the cutter being replaced, the same operation is repeated as at first, and the grooves are gradually cut to the desired depth by the successive addition of thin slips of paper. When the rifling is completed, an iron rod is placed in the centre of the barrel, and melted lead poured in, so as to occupy about eight inches of the barrel; which lead, of course, takes a perfect cast of the interior, and is afterwards charged with oil and fine emery, and drawn up and down the barrel to polish the inside, and remove the sharp edges left by the cutter. This operation is called *draw-boring*.

A barrel can be truly rifled by this means as by any other, if the rods be correctly made; but an improvement in rifling machines has been made, by which the twisted rod is altogether dispensed with, and any required curvature given by a round rod. The principal advantage of this machine is the facility it affords of varying the curvature of the spirals at plea-

sure, from a straight line to two turns in three feet. It would be difficult to convey any precise notion of this machine without the aid of engravings, which I have avoided, because so many would be necessary to illustrate every subject discussed in these papers; but I may simply state that a long square horizontal bar, which moves at each end in segments of a circle, is attached to the centre of the bench: this bar can be fixed at any angle of inclination: above this is a carriage freely traversing a rail-road, and in the middle of this carriage is the dividing plate and rifling rod, the latter being made to turn by means of a pinion-wheel and rack-work, which slides on the horizontal bar as the carriage is pushed backward and forward; all the other arrangements of wood and cutter being the same as with the twisted rod. This machine is now generally employ[illegible]st rifles, and the old plan for military ones.

A new method of rifling, with only two rather deep and wide grooves, has lately been introduced into this country from Hanover; with this important difference, however, that the Hanoverians employed a spherical ball, as usual in all other rifles, and gained no advantage; whereas the English use a spherical ball with a zone, or band, cast round it, which band enters the grooves of the rifle. Considerable difference

of opinion exists respecting the comparative merits of the old system of many grooves with a spherical ball, and the new one of two grooves with the banded ball. Having repeatedly tried both under a variety of circumstances, I think that there is very little difference in point of accuracy of flight, and that it is extremely difficult to determine which has the preference, provided both are properly rifled and correctly loaded. The two-groove rifle, however, possesses some important advantages, especially as a military arm, which have, in fact, secured to it the favourable opinion of the authorities at Woolwich, and caused its exclusive adoption for all rifle regiments. In the first place, it is much easier to load, as no mallet is required to make the ball enter the grooves, the band giving a sufficient hold on the ball to prevent it from stripping, and no more force is necessary than to load an ordinary gun; secondly, a greater degree of curvature can be given to the spirals in the barrel (a whole turn, in two feet six inches, being the military regulation), and thus a greater number of revolutions are given to the ball in its flight, than can be given to any other rifle, which rarely exceeds one turn in three feet, and which, if increased, would render a spherical ball liable to strip altogether, in consequence of being only slightly indented by the *lands* of the

rifle. Thirdly, in consequence of the greater hold the two grooves have on the banded ball, a larger charge of powder can be used, and greater velocity communicated to the ball, which enables it to overcome the resistance of the air more effectually. This, if true, may explain the apparent anomaly, that two-grooved rifles shoot more accurately at long ranges of 200 or 300 yards than others, although scarcely any difference can be detected at shorter ranges, or within 100 or 150 yards.

In all cases a well-greased patch of calico should be used, cut either square or round, and large enough nearly to envelope the ball; this is essential to all rifles, as it is easier to load, diminishes windage, prevents the barrel from *leading*, and increases accuracy of flight. I have found silk patches the best for very fine shooting, as they admit of using a larger ball than any other material without tearing or cutting, in forcing down the barrel. The balls may be kept inclosed in the patches, ready for use, by merely confining the four corners with a few stitches of thread.

Rifles with four grooves and two bands round the ball at right angles to each other have been proposed and tried by Dr. Mitford with good effect; but a sufficient number of experiments

have not yet been made to determine whether or not this plan possesses any advantage over the two grooves.

Some very ingenious machinery has recently been erected in the royal arsenal at Woolwich, to make leaden balls by compression instead of by casting. These bullets are perfectly solid, very accurate, and a few grains heavier than the cast ones (for it is not possible to cast a solid ball, as may be proved by making a perpendicular section, with a sharp knife, in the direction of the neck); therefore the compressed balls are decidedly the most perfect; but I am not aware that any great difference has been discovered in the accuracy of shooting; and with respect to economy, I must leave more competent judges to determine the question. The lead is first cast into long plummets or cylinders; then passed between grooved rollers, which slightly indent and compress them: another operation compresses them deeper, and in a contrary direction: a fourth process very nearly completes the string of balls, leaving them only surrounded by a thin skin of lead: the fifth, and last, punches the balls out by means of a treadle, and they fall into a trough, and roll away into tubs placed to receive them. The machinery is admirably constructed, and

does great credit to Mr. David Napier, the engineer, who is the inventor and maker.

It would be improper to omit in this place some notice of Captain Norton's percussion shells for rifles, which I have repeatedly tried, and never found one fail to strike on the foremost end, and explode at all distances, from 50 to 300 yards. In one experiment, I fired at two thicknesses of inch-and-half elm, lined with sheet iron, and containing between them a stratum of four inches of water; the shell passed through the whole at sixty yards' distance, and exploded a box of gunpowder on the other side. This leaden shell is cylindrical, with hemispherical ends, and cast with a cylindrical hole down the centre, leaving about a quarter of an inch solid at one end. It is only necessary to fill about three-fourths of this hole with fulminating powder, and insert a small wooden plug, fitting tightly and projecting very little beyond the surface of the lead: the rotation communicated by the rifling prevents the shell from turning, and the sudden compression on the wooden plug, when it strikes an object, is sufficient to explode the fulminating powder. Equal parts of chlorate of potash and sulphuret of antimony is the best composition for this purpose; or common gunpowder may be used instead, by

making small tin cylinders, the length of the hole in the shell, and putting large copper caps on to them; the outside of the caps fitting the hole in the lead. These shells should be cast in a mould, partially formed of a portion cut off the rifle barrel they are to be used with; so as to have elevations raised on their surface corresponding with the grooves in the rifle, to give a greater hold, and prevent stripping. This principle is not calculated for cannon; a very different arrangement being requisite, as with large charges of powder and great velocities the ball would always strip; and, independently of the expense of rifling cannon, there are insurmountable objections.

I have been eight years engaged in experiments with percussion shells for cannon, which are now in progress at Woolwich, having only commenced there with the present year (1840) by order of the Master-General of the Ordnance; but as they have been so often delayed from a variety of causes over which I have no control, little progress has been made, and if completed, it would be highly improper to give publicity to them.

After numerous experiments conducted privately, in 1832—1834, my shells were tried on board the *Excellent* at Portsmouth (1834-5), with considerable success, and received a most

favourable report, but remained in abeyance four years, when a probability of war taking place again brought the subject into notice, more especially as the French have already made considerable advances with these destructive missiles, and introduced them partially into their service, although at present very imperfect and uncertain.

The very recent accidents on board the *Medea* off Alexandria, and on board the *Excellent* at Portsmouth, in endeavouring to unscrew the ordinary fuzes of shells, prove that danger lurks where least suspected: if similar accidents had occurred with *percussion* shells, they would have been attributed to the principle itself, which would have been condemned altogether.

Any idea which can throw light upon unaccountable accidents [redacted], even if incorrect, be useful: I therefore venture to suggest the possibility of the fuze composition becoming altered in its properties by the action of time and moisture, or by extreme dryness; for it is a fact very little known, that the ordinary ingredients of gunpowder,—saltpetre, charcoal, and sulphur, exactly in the same proportions as they are employed in that manufacture, namely, 75, 15, and 10 parts of each respectively, can be rendered as

highly explosive as fulminating powder, simply by an alteration in the processes of granulation and drying; so that gunpowder, thus made, would not bear the friction of the grains against each other, and would explode by merely rolling in a cask. Such gunpowder is extremely strong, and Sir William Congreve tried many experiments with it, but it was too dangerous to introduce into service, and, like many other curious facts, is almost forgotten. May not accidents arise, therefore, from incidental causes producing unintentionally such an arrangement of the particles as I have described?

As a familiar illustration (and the more homely the better), barley-sugar is perfectly clear and bright when first made and dry; but if in this state it be inclosed in glass and perfectly secured from the atmosphere, it crystalises slowly and becomes opaque and white by the action of light only and in a dry situation. This fact is so well known to grocers, that they generally put twisted sticks of coloured glass into their jars as a representative of the real article in their windows.

Fuze composition is liable to similar changes by the action of heat and moisture, and it is possible, from the foregoing statement, to imagine that many occurrences which are conceived to be owing to negligence, inattention to

orders, the interposition of gritty substances, and a variety of circumstances, might, if the truth were known, originate in natural causes, which no caution could have foreseen or prevented.

As the experiments just referred to have occupied much of my time at different periods, I cannot help remarking how singular it is, that in a country like this, where everything relating to gunnery, either naval or military, must be tried and approved by the "Select Committee" at Woolwich, (appointed by the Board of Ordnance,) before it can be adopted in the service, there should be no range sufficiently long for the purpose of making such experiments as are constantly required, and that there should be no power to prevent vessels anchoring immediately behind the *butt* in the marshes, and thus suspending important experiments at any moment from the fear of doing some injury. It is true that an order to that effect exists, but without the power to enforce obedience. This is an evil which has been rapidly increasing for many years, in consequence of the introduction of steam and the increased navigation of the river, so that a shot can only be obtained as it were by stealth, and with the greatest precaution. The remedy has also, for a long period, been equally obvious and attainable. At present the marsh

lands, parallel with the river, could be purchased for a moderate sum, to the extent of nearly four miles, as they are comparatively of little value; in a few years they will probably be taken by engineers or by companies to build manufactories, every spot near the banks of the river being already occupied, and then the Government will find it necessary to purchase at an exorbitant price what might have been obtained for a mere trifle compared with so great a national benefit.

The Congreve rocket being a missile *sui generis*, it is difficult to know where to place a few observations that may not be wholly irrelevant. These projectiles, although of modern date in European warfare, have long been known in India; but as they were never employed by us until suggested by Sir William Congreve, the whole merit of bringing them to perfection belongs to him as much as if he had been the originator of the invention. There can be no doubt that they are most powerful auxiliaries in the art of war.

Tippoo Saib used them with considerable effect against the English at the siege of Seringapatam in 1799; and it was only in 1805 that Colonel Congreve exhibited them to the ministers at Woolwich; soon after which they were tried on a larger scale in the bombardment

of Boulogne, Copenhagen, and other places. Towards the end of the war a rocket corps was established, some part of which joined the allied army and fought at the battle of Leipsic in 1813.

Many foreign writers affect to treat them with contempt, and endeavour to impress on the minds of their countrymen the belief that rockets owe their efficacy more to the moral effect produced on an enemy than to their own destructive powers, by inspiring confidence on the one side and terror on the other; but this is a very erroneous opinion, as they possess many advantages over cannon in certain situations and circumstances, particularly in mountainous countries: they are capable of projecting almost every variety of shot and shells that can be thrown from cannon, howitzers, and mortars, within certain limits, either for bombardment, conflagration, or field service, and they are applicable to new and important purposes to which they have never yet been applied.

Numerous attempts have been made to analyse them with partial success as far as the nature and proportion of the ingredients are concerned; but fortunately for England, in this respect as in many others, there is one ingredient which defies analysis — that is, En-

glish industry and perseverance. There are very few governments in the world that would be able or willing to expend such enormous sums of money as were required to bring these projectiles to perfection; therefore we ought certainly to derive some exclusive advantages for so large an outlay of capital. If, however, the ingredients and the accurate proportions for each description of rocket were to be published (which has never yet been done and never ought to be), we might still confidently anticipate a superiority over our rivals in this manufacture as well as in many others. We sell our machinery to all the world because we feel confident that before it can come fairly into operation, our own improvements will almost supersede the latest inventions exported: we exhibit our arsenals and dock-yards to all strangers, perhaps too indiscriminately: we expose the secrets of our manufactories to whoever desires to possess, see, or understand them; yet we continue, as we have ever done, to maintain our position as one of the most powerful nations in the universe.

Having recently considered this subject with some attention, I feel confident that in the event of another war, rockets will assume a new and important feature; and even if economy were the sole object, they are not more expensive than

the usual apparatus of war, taking transport into consideration. Economy, however, at the commencement of a war, is always the greatest possible extravagance.

The experiments already commenced are not sufficiently matured to enlarge upon further. I have frequently been asked if I were "the man in the *Times*," but I here beg to disclaim all idea of ever being able to blow a three-decker into small fragments at six miles distance!

On Wadding for Fowling Pieces.

To many persons it may appear immaterial what substance is interposed between the powder and shot in loading; but all experienced sportsmen know that there is a considerable difference in the shooting of the same gun, with the same charge, by merely altering the quality or substance of the wadding.

The old method of loading with paper is inconvenient, and liable to throw the shot in clusters: the latter objection also applies to cartridges. A great improvement in portability was effected by the introduction of card or pasteboard, cut to suit the caliber; but, until the invention of the ELASTIC CONCAVE WADDING few

persons appear to have devoted much attention to the subject.

When it is known that in an ordinary charge (1½ oz.) of No. 6. shot there are upwards of 400 pellets, and that at forty yards the average number thrown into a sheet of paper, 18 inches by 24, does not usually exceed eighty or ninety, it is evident that more than three-fourths of the charge is rendered useless at that distance, and of course a greater proportion as the distance increases.

This circumstance induced me, in 1824 and 1825, to investigate the subject, and to ascertain, if possible, what improvements might be effected by combining a new system of boring with a change in the nature and form of the wadding.

After numerous experiments with cork, leather, and other substances, I was enabled to bring to perfection a wadding which far surpassed my most sanguine expectations.

Before I attempt to demonstrate the advantages of this invention, I will state the defects of card or pasteboard.

My first proposition is, *that the common card wadding invariably turns in the barrel, either at the moment of explosion, or immediately after.*

Should this be doubted, I ask if it be possible

to imagine that the weight of a loose body, like shot, contained in a cylinder which is always carried in an inclined position, can press equally on every part of a thin card on which it is poured?

If the pressure be not equal, the moment the powder is ignited, the card nearest to the powder must give way on that side which is opposed to the least resistance; and the other card, either from inequality of pressure or friction: *the latter cause* is alone sufficient to prevent the possibility of a card wadding passing along a barrel without turning. A simple experiment will more clearly elucidate this point: — Close a cylindrical glass tube at one end; load it like a gun barrel with card wadding and an ordinary charge; hold the tube in an horizontal position, and slightly agitate it for a few minutes; the shot will not remain in a compact cylindrical mass, but assume an inclined position; the greatest weight being on the under side of the tube; or, force air suddenly through an aperture in the lower end of the tube, and the cards will turn.

Admitting that the cards turn, it follows, that a considerable portion of the elastic force of the powder must be lost by escaping through the charge of shot; in the same manner as the power of a steam engine would be decreased by the

escape of vapour, if the piston did not fit the cylinder.

The shot, become enveloped in flame, are heated, and in that state give off their lead to the inside of the barrel much more readily than when cold. In a double-barrelled gun, the firing of one barrel several times moves the charge in the other; so that if it be discharged without the ramrod having been previously introduced, there is a probability of injuring the barrel; or, if the gun be held with the muzzle downwards, the shot frequently turn the card, and escape.

The corollary to my first proposition is, *that the shot strike against each other and the inside of the barrel, forming angles which impede their velocity.* This must take place if the wadding turn, as the impetus given to the shot cannot be parallel to the axis of the barrel; consequently angles are formed, and continue to increase, by the collision of the shot with each other; so that, when liberated from the barrel, many are nearly spent, and fall at short distances, or are dispersed laterally.

To illustrate this, suppose a single shot to be impelled in an angular direction through a long cylindrical tube or barrel, that angle would be

repeated throughout the whole length of the cylinder, and the shot would fly off in an oblique direction.

Having thus attempted to explain the disadvantages of the common wadding, I will endeavour to prove by theory and experiment, that the elastic concave wadding overcomes all the objections stated, and possesses many peculiar advantages.

The first in importance is, the great improvement produced in the shooting, both in strength and closeness.

Secondly. That the gun remains clean much longer, and does not lead.

Thirdly. This wadding will not ignite, nor can any portion ever remain in the barrel.

Fourthly. The discharge of one barrel does not displace the charge in the other, and therefore every chance of accident is removed.

I have adopted the concave form, in order to place the greatest quantity of powder and shot in the centre of the barrel, and thus invariably oppose the greatest resistance to the strongest impulse, which, combined with the thickness of the edge, prevents the possibility of the wadding turning, and keeps the shot in a compact cylindrical mass until delivered from the barrel, by which closeness is obtained; and as no portion

of the gases generated by the ignition of the powder can escape, the velocity is, consequently, much increased.

This wadding, being made of wool, is very elastic; and not only wipes the barrel clean every time it is loaded, but being so slow a conductor of caloric, the heat of the flame does not penetrate to the shot, and the leading is, in a great degree, prevented. An inspection of the wadding, after firing, will prove this assertion, as it will be found only singed on the side in contact with the powder, while the upper surface is perfectly white and uninjured.

I invariably use a concave wadding *over the powder*, but a flat and thinner *woollen* one (or even pasteboard), may be substituted over the shot: the pasteboard wadding does not, however, keep the whole charge so compact as the woollen. Many persons may object to carry two kinds of wadding; in which case, the concave may be used over powder and shot, and will be found considerably to improve the shooting of every gun.

About one-third the diameter of the bore is sufficient for the thickness on the edge, *if concave;* but a greater thickness is required to prevent turning, if used flat; and the charge occupies more space in the barrel, not having the hollow on each side to fall into.

This wadding is now so universally known and its advantages are so fully established after fifteen years' experience, that it may appear almost superfluous to notice it further than to state that the average of numerous experiments made at the period before alluded to, proved that the strength and closeness of the shooting was increased more than one-fifth in every instance, with the same guns, when compared with common pasteboard wadding and equal charges of powder and shot. When this wadding was first invented, numerous testimonials of its superiority were sent from the most celebrated sportsmen in England: the annexed one, from Colonel Hawker, an authority so justly established and appreciated, will be sufficient[1]:—

Longparish House, Dec. 1st. 1827.

Gentlemen,

I have tried your "ELASTIC CONCAVE WADDING" with a large inch and a half gauge duck-gun, which, from being on the largest scale, is, of course, the truest criterion to judge of its effects: and I have no hesitation in pronouncing it superior to all other wadding that I have yet made use of. Indeed, the other kinds of wadding so decidedly failed, that, until yours was brought out, I found nothing so good as common oakum. You are at liberty to make any use you please of this certificate; and if the gunmakers attempt to cry it down, refer them to me.

I am, Gentlemen, yours, &c.

P. HAWKER.

To Messrs. Wilkinson & Son.

The following experiments were made in 1827 with two double-barrelled guns, loaded alternately with the concave wadding and blue pasteboard: —

FIRST EXPERIMENT,

With a double-barrelled gun, 2 ft. 4 in., and 18 bore, at 40 yards distance; charge of powder, $2\frac{3}{4}$ drs.; shot, $1\frac{1}{4}$ oz.

Concave Wadding over Powder and Shot.			Pasteboard Wadding over Powder and Shot.			
Order of Firing.		Number of Shot thrown into a Target 18 by 24.	Order of Firing.		Number of Shot thrown into a Target 18 by 24.	Difference in favour of Con. Wad.
1	left Bl.	100	3	left Bl.	72	28
2	right	106	4	right	61	45
5	left	97	7	left	67	30
6	right	88	8	right	59	29
9	left	101	11	left	65	36
10	right	87	12	right	69	18
Total - -		579	Total - -		393	186

Making an average of *thirty-two* more shot thrown into the space of a sheet of paper, merely by the change of wadding. Eight sheets of stout brown paper were then folded in four, thus forming thirty-two thicknesses: *eleven shot* were driven through twenty-nine of them when the concave wadding was used, and *five* only through twenty-two thicknesses with the pasteboard.

SECOND EXPERIMENT,

With a double gun 2 ft. 8 in., and 14 bore, at 40 yards; charge of powder, $3\frac{1}{4}$ drs.; shot $1\frac{1}{2}$ oz.

Concave Wadding over Powder and Shot.			Pasteboard Wadding over Powder and Shot.			
Order of Firing.		Number of Shot thrown into a Target 18 by 24.	Order of Firing.		Number of Shot thrown into a Target 18 by 24.	Difference in favour of Con. Wad.
1	left Bl.	118	3	left Bl.	101	17
2	right	107	4	right	86	21
5	left	123	7	left	91	32
6	right	116	8	right	87	29
9	left	108	11	left	94	14
10	right	105	12	right	89	16
Total - -		677	Total - -		548	129
4 shot driven through 36 thicknesses.			1 shot driven through 27 thicknesses.			

Making an average of *twenty-one* more shot thrown into a sheet of paper when the concave wadding was used.

PART V.

ON THE HISTORY OF GUNPOWDER.

Of all the numerous discoveries that have been made since the Creation, perhaps there is none which has produced more important consequences to mankind than that of gunpowder; and it has been observed by Kock, in his Revolutions of Europe, that there is no invention which arrests our attention more; as by introducing fire-arms and a new method of fortifying, attacking, and defending towns, it wrought a complete change in the whole art and tactics of war.

The question has often been warmly debated, whether this discovery has been useful or pernicious to the human race, and there can be no doubt that the immediate operation of gunpowder is more terrific and destructive than that of any of the former instruments of war, and that it has added greatly to the means of offence: but, as hostilities between nations are rarely terminated until the mutual mischief produced has risen to a degree which causes the evil to be severely felt, or until one of the parties

is reduced to the necessity of submission, it is perhaps of small importance by what means this state of things is brought about. Battles are apparently not more bloody than formerly; and towns are not more frequently laid in ashes, or countries made desolate. One of its advantages can scarcely be denied to be advantageous to society, namely, that it has given a decided superiority to civilised over barbarous nations, by intimately connecting the progress of science with improvements in the art of war.[1] Indeed, the more dangerous and destructive war can be rendered, the less probability there will be of rashly undertaking it, for if the chances of destruction be greatly increased, fewer persons will risk their lives in the quarrels of others; therefore, however paradoxical it may at first appear, whoever increases the powers of destruction is engaged in the cause of humanity.

The Greek fire has been highly extolled for the wonderful effects it produced; but this, like all other contrivances of great novelty, owed much of its effect to the terrors and imagination of the beholders, and was most probably of more recent invention than gunpowder. It is said by the Oriental Greeks to have been discovered by Callinicus, an architect of Heliopolis, or Balbeck,

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[1] Rees's Cyclopædia.

who lived in the reign of the emperor Constantine Pogonatus; who, it is reported, forbid the art of making it to be communicated to foreigners, but it was at length known and in common use among the nations confederated with the Byzantines.[1]

The accessions to the knowledge of our ancestors in the art of war, in consequence of the Crusades, were singularly conspicuous: from the Saracens they obtained a sort of wildfire, which could only be extinguished by dust or vinegar; it appears to have been compounded of the gum of the pine, and other resinous trees reduced to powder, with sulphur; to which was added, naphtha and other bitumens, and probably nitre[2]: it is supposed to have been the invention of some Arabian chemist, and is much spoken of in all the histories of the Holy Wars, as being frequently employed with success by the Saracens against the Christians. Procopius, in his History of the Goths, calls it Medea's oil, considering it as an infernal composition prepared by that sorceress. It is also said to have been known in China in 917, 300 years after Constantine Pogonatus, under the name of *the oil of*

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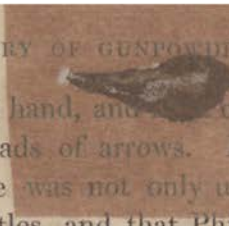
[1] Grose, Hist. Eng. Army, vol. ii. p. 309.

[2] The Persians call saltpetre *Chinese salt;* the Arabs, *Chinese snow;* which tends to prove that they received it from the East.

the cruel fire, was carried thither by the Kitan Tartars, who had it from the King of Ou.[1]

Joinville, who was an eye-witness, describes its appearance thus: "It was thrown from a petrary, and came forwards as large as a barrel of verjuice, with a tail of fire as big as a great sword, making a noise like thunder, and seeming like a dragon flying through the air: the light it gave out from the great quantity of fire rendered the camp as bright as day; and such was the terror it occasioned among the commanders in the army of St. Louis, that Gautier de Cariel, an experienced and valiant knight, advised, that as often as it was thrown they should prostrate themselves on their elbows and knees, and beseech the Lord to deliver them from that danger against which He alone could protect them." This counsel was adopted and practised, but the effects of this fire do not seem to have justified the terror it occasioned: a few of their machines were inflamed, but extinguished; though Geoffrey de Vinesauf, who accompanied Richard I. to the Crusades, says that it could not be extinguished by water, but that sand thrown upon it abated its violence, and vinegar poured upon it put it out. It was thrown by

[1] L'Esprit des Croissades, Amsterdam, 1780. Ducange, Anna Commena, Père Daniel, &c.



machines, by the hand, and cross-bows, fastened to the heads of arrows. Father Daniel says this wild-fire was not only used in sieges, but even in battles, and that Philip Augustus, king of France, having found a quantity of it ready prepared at Acre, brought it with him to France, and used it at the siege of Dieppe, for burning the English vessels in that harbour.

The Greek fire was used long after the invention of fire-arms. When the bishop of Norwich besieged Ypres, A. D. 1383, the garrison is said by Walsingham to have defended itself so well with stones, arrows, lances, Greek fire, and certain engines called guns, that they obliged the English to raise the siege with such precipitation, that they left behind them their great guns, which were of inestimable value.

It is perhaps not singular that the invention of gunpowder should be so completely involved in obscurity — indeed this very fact is one proof of its great antiquity. I therefore venture to offer what I conceive to be an original and plausible theory on this subject. It has always appeared to me highly probable that the first discovery of gunpowder might originate from the primeval method of cooking food by means of wood-fires, on a soil strongly impregnated with nitre, as it is in many parts of India and China. It is certain that from the moment when the

aborigines of these countries ceased to devour their food in a crude state, recourse must have been had to such means of preparing it, and when the fires became extinguished, some portion of the wood partially converted into charcoal would remain, thus accidentally bringing into contact two of the principal and most active ingredients of this composition, not once, or twice, but daily and hourly, under such circumstances as could hardly fail to produce some slight deflagration whenever fires were re-kindled on the same spot; which at first must excite some surprise and possibly give rise to the idea of enchanted ground, until a repetition of the effect might induce some priest or chief of superior intelligence to ascertain the cause, and by turning it to superstitious advantage, establish an ascendancy over the weaker minds of his followers. The presence of sulphur, although advantageous, is not absolutely necessary to the constitution of gunpowder, as will be hereafter shown; therefore it is certainly possible that such a combination of favourable circumstances might lead to the discovery, although the period of its application to any useful purpose may be very remote from that of its origin.

The common tradition of Bartholdus Schwartz having invented gunpowder and artillery about 1320, is without the slightest foundation, but he

might probably have suggested the simplest application of it to warlike purposes, in consequence of some accidental explosion while mixing the ingredients in a mortar: indeed the form as well as the name of the old species of artillery which was employed to throw large stone bullets at an elevation, strongly corroborate this conjecture. It frequently happens that the same discovery is made by different persons engaged in similar pursuits; but Schwartz cannot claim any originality of invention, as our countryman Roger Bacon, who was born in 1214, and whose works were published at Oxford about 1267, expressly mentions the ingredients of gunpowder, not as any new discovery, but as a well-known composition used for recreation, and he describes it as producing a noise like thunder, and flashes like lightning, but more terrible than those produced by nature, and adds that it might be applied to the destruction of an army or city: he supposes that by some artifice of this kind Gideon defeated the Midianites with three hundred men.[1]

In another treatise having mentioned the same subject in different words, he adds, "Et experimentum hujus rei capimus ex hoc ludicro puerili quod fit in multis mundi partibus, sci-

[1] Judges, chap. vii.

licet, ut instrumento tacto ad quantitatem pollicis humani, ex violentia illius salis, qui SAL PETRÆ vocatur, tam horribilis sonus nascitur, in ruptura tam modicæ rei scilicet modici pergameni, quod fortis tonitrus excedere rugitum, et coruscationem maximam sui luminis jubar excedit." [1]

Bacon in his treatise *De Secretis Operibus Artis et Naturæ et de Nullitate Magiæ*, cap. 6., which was undoubtedly written before his *Opus Majus*, says, "that from saltpetre and other ingredients we are able to make a fire that shall burn at any distance we please." Now Dr. Plott[2] assures us that these "other ingredients" were explained (in a MS. copy of the same treatise in the hands of Dr. G. Langbain, seen by Dr. Wallis,) to be sulphur and wood-coal." The writer of the life of Friar Bacon, in the *Biographia Britannica*, vol. i., says, that Bacon himself has divulged the secret of this composition in a cipher, by transposing the letters of the two words in chap. xi. of the before-mentioned treatise, where it is thus expressed: "Sed tamen salis Petræ *lura nope cum ubre* (i. e. carbonum pulvere) et sulphuris; et

[1] Vide Dr. Jebb's Preface to his edition of Bacon's *Opus Majus*.

[2] History of Oxfordshire, p. 236. &c.

sic facies tonitrum et coruscationem, si scias artificium :" and from hence Bacon's biographer apprehends the words *carbonum pulvere* were transferred to the sixth chapter of Dr. Langbain's MS.

It is supposed [1] that Bacon acquired his knowledge of this composition from a treatise on fire-works, entitled *Liber Ignium* [2], written by Marcus Græcus, who lived about the end of the eighth century. The MS. is still extant, and is quoted by the Reverend Mr. Dutens, in his "Inquiry into the Origin of the Discoveries attributed to the Moderns," in order to prove that gunpowder was known to the ancients. The composition therein prescribed is six pounds of saltpetre, two pounds of charcoal, and one pound of sulphur, well powdered and mixed together in a stone mortar, which is a far better composition than many in later use; but the inferiority of the powder in later times might not arise from ignorance of better proportions, but in consequence of the weakness and bad construction of the ar-

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[1] Robins on Gunnery, 1742.

[2] This MS. is in the Royal Library at Paris. Dr. Mead and afterwards Dr. Hutton had a copy of it; also cited in Dr. Jebb's Preface to Bacon's *Opus Majus*. The title of the manuscript runs thus: "Incipit liber ignium a Marco Græco prescriptus, cujus virtus et efficacia est ad comburendum hostes, tam in mari quam in terra."

tillery at that period, which was formed merely of bars of iron hooped together with iron rings. Tartaglia[1] sets down twenty-three different compositions made use of at different times; the first of which being the most ancient, consists of equal parts of nitre, sulphur, and charcoal. Mr. Dutens[2] carries the antiquity of gunpowder much higher, and refers to the accounts given by Virgil[3] and others, of Salmoneus' attempt to imitate thunder, presuming from hence that he used a composition of the nature of gunpowder. The Brahmans did the same, according to Themistius[4], and also the Indians, whose practice is recorded by Philostratus[5] in his life of Apollonius Tyanæus, written about 1600 years ago, in which there is the following passage concerning a people of India, called Oxydracæ: —

"These truly wise men," says he[6], "dwell

[1] Quesiti e Inventioni Diversi, lib. iii. ques. 5. Venise, 1546.

[2] Hyginus, Fabul. 61. 650.; Eustathius ad Odyss. Λ, 234. p. 1682. l. 1.; Valerius Flaccus, lib. i. 662.; Dion Cassius, Hist. Rom. in Caligul. p. 662.; and Johannes Antiochinus, Chronica apud Peiresciana Valesii, Paris, 1604, p. 804.; all quoted by Dutens in his "Inquiry, &c."

[3] Æneid. vi. 585.

[4] Orat. xxvii. p. 337.

[5] MS. and translation in the British Museum, lib. ii. c. 33.; lib. iii. c. 13.

[6] Lib. ii. c. 14. Grey's Gunnery (1731).

between the rivers Hyphasis and Ganges; their country Alexander never entered, deterred, not by fear of the inhabitants, but, as I suppose, by religious motives, for, had he passed the Hyphasis, he might doubtless have made himself master of all the country round them: but their cities he never could have taken, though he had led a thousand as brave as Achilles, or three thousand such as Ajax to the assault; for they come not out to the field to fight those who attack them; but these holy men, beloved by the gods, overthrow their enemies with tempests and thunder-bolts shot from their walls. It is said that the Egyptian Hercules and Bacchus, when they overran India, invaded this people also, and having prepared warlike engines attempted to conquer them: they, in the meanwhile, made no show of resistance, appearing perfectly quiet and secure; but, upon the enemy's near approach, they were repulsed with storms of lightning and thunder-bolts hurled upon them from above."

This is the most striking illustration of the antiquity of gunpowder with which I am acquainted, for if some such composition be not implied in the foregoing quotation, it must remain perfectly unintelligible, as we are too far advanced in knowledge to admit that the gods interfered in this matter.

It is also known that iron rockets have been used in India as military weapons time out of mind.

Citizen Langles, in a memoir read before the French National Institute, contends that gunpowder was conveyed to us by the Arabs on the return of the Crusaders, and that the Arabs employed it at the siege of Mecca in 690. He says that they derived it from the Indians.

Sir George Staunton observes, that gunpowder in India and China seems coeval with the most distant historic events, and that the Chinese have at all times applied it to useful purposes, as the blasting of rocks, and also in the preparation of fire-works, in which they greatly excel other nations.

Halhed, the translator of the Gentoo laws, finds fire-arms, gunpowder, and cannon mentioned in that code, which was supposed by some persons to be at least coeval with Moses: he observes, that "it will no doubt strike the reader with wonder to find a prohibition of fire-arms in records of such unfathomable antiquity, and he will probably from hence renew the suspicion which has long been deemed absurd, that Alexander the Great did absolutely meet with some weapons of that kind in India, as a passage in Quintus Curtius seems to ascertain. Gunpowder has been known in China as well

as in Hindustan far beyond all periods of investigation. The word fire-arms is literally Shanscrit, Agnee-aster (agnyastra), a weapon of fire; they describe the first species of it to have been a kind of dart, or arrow tipt with fire, and discharged upon the enemy from a bamboo. Among several extraordinary properties of this weapon, one was, that after it had taken its flight, it divided into several separate streams of flame, each of which took effect, and which, when once kindled, could not be extinguished; but this kind of agnee-aster is now lost. Cannon, in the Shanscrit idiom, is called Shĕt-aghnee (sataghni), or the weapon that kills a hundred men at once, from shĕtĕ (sata), a hundred, and ghĕnĕh (hana), to kill, and the Pooran Shasters, or histories, ascribe the invention of these destructive engines to Bĕĕshŏŏkermā (Viswakarma), the artist, who is related to have forged all the weapons for the war which was maintained in the Suttee Jogue between Dewtā and Ossoor (devata and asura), or the good and evil spirits, for the space of 100 years."[1]

Kock[2], whom I have before quoted, observes, that the invention of gunpowder, which produced a new era in the annals of warfare, comprises se-

[1] Introduction, p. lii. [2] Revolutions of Europe.

veral discoveries which it is necessary to distinguish from each other — first, the discovery of nitre, the principal ingredient in the composition of gunpowder, and the cause of its detonation; secondly, the mixture of nitre with sulphur and charcoal, which, properly speaking, form the invention of gunpowder; thirdly, the application of gunpowder to fireworks; fourthly, its employment as an agent or propelling power for throwing stones, bullets, or other heavy and combustible bodies; fifthly, its employment in springing mines and destroying fortifications. All these discoveries belong to different epochs. The knowledge of saltpetre or nitre, and its explosive properties called detonation, is very ancient; most probably it was brought to us from the East (India or China), where saltpetre is found in a natural state of preparation; it is not less probable that the nations of the East were acquainted with the composition of gunpowder before the European and that it was the Arabs who first introduced the use of it into Europe, where it is ascertained to have been employed as an agent for throwing balls and stones about the commencement of the fourteenth century, and it was the Moors who first availed themselves of its advantages in their wars with the Spaniards. From Spain the use of gunpowder and artillery passed to France, and thence it

gradually extended itself all over the other states of Europe.

As to the application of powder to mines and to the destruction of fortifications, it does not appear to have been in practice before the end of the fifteenth century. The ancient mode of mining was to support the superincumbent strata with wooden pillars in the progress of the work, and afterwards setting fire to the supports, the earth fell in, and either overturned the ponderous machines above, or threw down the walls and towers.

When we reflect on the various circumstances which tended to check the progress of fire-arms and the improvement of artillery for so long a period after the invention of gunpowder, we shall cease to feel any surprise. Custom made most people prefer the ancient engines of war: the construction of artillery was very awkward and imperfect, the manufacture of gunpowder so bad that it could produce little effect compared with that in present use; there was a general aversion to the newly-invented arms, as contrary to humanity, and calculated to extinguish military bravery; and, above all, knights (whose science was rendered entirely useless by the introduction of fire-arms) opposed with all their might this invention; to which may be added the great cost and difficulty of procuring gun-

powder.[1] Camden in his life of queen Elizabeth says, that she was the first who procured it to be made in England, that she might not pray and pay for it also to her neighbours.

Nye, in his treatise on fire-works, gives the proportions of the ingredients and the dates when they were used: thus, in 1380, equal parts of each were employed (which would be about as efficient as a common squib of the present time); in 1410, three parts saltpetre, two sulphur, and two charcoal; in 1520, for the best powder, four parts saltpetre, one sulphur, and one charcoal; in 1647, six saltpetre, one sulphur, and one charcoal; and afterwards, five saltpetre, one sulphur, and one charcoal: in fact, gunpowder was merely these substances combined with little or no purification, according to the skill of the pyrotechnist, and it was not corned or grained as at present, but remained in its mealed state, and was called serpentine powder in several accounts of stores in the time of Edward VI. and Elizabeth.[2] Soon after this period two kinds of powder were used, one in its mealed state, for priming only, as it more readily ignited by

[1] Grose, Hist. Eng. Antiquities, &c.

[2] "The oldest method of making powder was equal parts of each ingredient."— Peter Hawthorn, 1573.

the match; the other corned, or granulated, for the charge in the gun-barrel.[1]

From this time progressive improvements have been made in the manufacture, until it has arrived at the greatest state of perfection of which it appears to be capable.

Some idea of the importance of gunpowder, as a national manufacture, may be formed by an estimate of the enormous quantity employed in sieges and warfare generally: as an illustration I shall merely select some few examples. At the siege of Ciudad Rodrigo in January, 1812, 74,978 lbs. of gunpowder were consumed in 30½ hours; at the storming of Badajos in March of the same year, 228,830 lbs. in 104 hours, and this was from the great guns only[2]; at the first and second sieges of San Sebastian, 502,110 lbs.[3]; and at the siege of Zaragoza, the French exploded 45,000 lbs. of powder in the mines, and threw 16,000 shells during the bombardment.[4] To which may be added that some of our private manufacturers turn out from 8,000 to 10,000

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[1] Seaman's Dictionary by Sir Henry Manwayring, art. *Powder*. Presented to the Lord Buckingham in the reign of Charles I.

[2] The British Gunner. Taken the powder at the usual service charge of one third weight of the ball.

[3] From the returns made at the Royal Arsenal, Woolwich.

[4] Napier's History of the Peninsular War, vol. ii. p. 46.

barrels[1] of powder a year in time of peace, and from 10,000 to 14,000 barrels during war.

The quantity of powder received and proved at the royal magazines from Faversham, and the several powder makers contracting with government, amounted, during the seven years from 1776 to 1782 inclusive, to 244,349 barrels of 100 lbs. each, being equal, on an average, to 3,490,700 lbs. annually.[2] The quantity of powder in store at the different magazines in Great Britain, Guernsey, Jersey, and the Isle of Man in 1783, was about 80,000 barrels.

In the following Part I purpose to describe, as briefly as possible, the present method of manufacturing gunpowder, as adopted at one of the most celebrated powder mills[3] in England, having repeatedly witnessed every operation there.

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[1] A barrel of powde[illegible]0 lbs. weight.

[2] The late R. Coln[illegible]sq., Faversham Mills. Official Returns.

[3] Pigou and Wilks, [illegible]rd.

PART VI.

ON THE MANUFACTURE OF GUNPOWDER.

THE only ingredients in the manufacture of gunpowder are saltpetre, charcoal, and sulphur, and it has been decided by all nations that at least three fourths of the composition should be saltpetre, and the remaining fourth charcoal and sulphur, the excess being always of the charcoal.

The proportions adopted in England for military purposes are in 100 parts — 75 saltpetre, 15 charcoal, 10 sulphur: other nations vary these proportions in a trifling degree; but as the powder manufactured in England is preferred all over the world to that of any other country, and is decidedly superior (particularly the sporting powder[1]), we may safely infer that we are not far from being correct, although the excellence of English powder may depend less on this ac-

[1] The best sporting powder contains a larger proportion of saltpetre, and is longer grained: it differs also in every process of manipulation a

count than on the judicious purification and perfect admixture of the ingredients, on which mainly depends the superiority of the powder.

It is however curious[1] to remark that some gunpowder obtained from China by the Hon. George Napier, was analysed and found to contain, in 100 parts, 75·7 saltpetre, 14·4 charcoal, 9·9 sulphur; so close an approximation to our own proportions as to induce a belief that it was not accidental, and that the Chinese might have returned to us some of our own powder. Should this not be the case, it is highly probable that as they so scrupulously adhere to the "wisdom of their ancestors," the same proportions may have been employed by them for ages.

The theoretical proportions[2] are those in which the carbon will just consume the oxygen of the nitre, and the sulphur exactly as much as will saturate the potas[illegible]his will be effected by 1 atom each of n[illegible]and sulphur, and 3 atoms of carbon; or, ni[illegible]5·5, charcoal 16·2, sulphur 15. These [illegible]0 parts give, nitre 75·4, charcoal 12·8, [illegible] 11·8. It is, however, practically be[illegible]ve an excess of char-

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[1] Robert Colman, Re[illegible], Waltham Abbey.

[2] Brewster's Encyclop[illegible]

coal and sulphur; for as new combinations are formed at the moment of ignition, and as bodies can combine chemically only in definite proportions, any deficiency below a certain quantity would be equivalent to the omission of the whole, therefore the proportions generally adopted may be considered as perfect as possible.

The first consideration in the manufacture of gunpowder is to obtain each ingredient separately in a state of purity, otherwise it would be impossible with the greatest care to make good powder.

The saltpetre employed in this country is almost wholly that which has been either imported from India, or extracted from damaged powder.

In the year 1600, the East India Company obtained their first charter, and in 1628 they published their petition and remonstrance to the House of Commons, from which it appears that they had a large quantity of saltpetre in their stores, and that they were made about thirty barrels of powder at the mills from such refined saltpetre as they got from India. By their charter granted in 1693, they were bound annually to supply government with 500 tons of saltpetre, at 80*l.* per ton in time of peace, and 45*l.* per ton during war: a similar

provision continued until the expiration of their charter, a few years ago.

England and Holland supplying themselves from India[1] and China, paid little attention to the artificial modes of obtaining this salt, which abounds in the common soil of those countries, as well as in Egypt, South America, Spain, and some others; but the immense consumption of it in the manufacture of gunpowder has made it a desideratum to obtain it by artificial means, and in France and Germany it has been formed in great abundance by what are called *artificial nitre beds.*

These consist of long narrow heaps of animal and vegetable matter, collected and mixed with calcareous and other earths: sheds are thrown over these heaps to protect them from the rain, and keep up the heat; but water is occasionally poured over them to assist the putrefactive fermentation. The [illegible]or saltpetre effloresces on the surface, and [illegible] swept away from time to time; these swee[illegible] are purified by lixiviation and crystallizatio[illegible]

In Switzerlan[illegible]e nitre beds are frequently

[1] Rees's Cyclop[illegible] *Salt.* In Calcutta alone from 7000 to 8000 [illegible] manufactured annually. In France there was manufa[illegible] by artificial means in 1691, 3,647,767 lbs.

connected with stables on a large scale, to take advantage of animal excrement.

The sweepings of the streets with the offal of a small district in Hanover, produced the chief of the saltpetre that was used in that electorate. And Dr. Franklin states, that in America the manufacture of this salt, from the before-mentioned substances, was so simple and carried on at so small an expense, that only one old man and his wife were employed in it.

The King of Prussia[1] was so desirous of establishing saltpetre works in his dominions, that he obliged his farmers to build their fences of common earth, mixed with straw: these substances in a few years decomposed, and were either shaved, or wholly taken down, according to their state, and are said to have afforded a large quantity of saltpetre. But the most curious description of this process is given by Glauber, the chemist, who says, "I will show a way to those who have no inheritance left them by their parents, nor have any thing come to them by marriage, by what means they may with little labour and trouble get [illegible] for their children." He then minutely [illegible] the process,

[1] Considerations on the [illegible] of the Production of Saltpetre in England, by [illegible] Denries.

which is far too tedious to repeat, but it consists in digging a pit, which is to be filled with the refuse of all animal and vegetable matter, and "after a time to extract the saltpetre therefrom, and ascertain what treasure hath been amassed even whilst they slept." Many vegetables[1] furnish nitre in considerable quantity, particularly those which are poisonous, or possessing much odour: the extracts of henbane, hemlock, and quassia, after a length of time become covered with crystals of nitre.

Nitre or saltpetre[2] (chemically called nitrate of potassa) is usually imported in bags of coarse sacking, containing about 154 lbs. in each, and in this state it is called by powder makers *grough petre*, being also distinguished by the terms *private petre* and *Company's petre*, implying that which has been imported by the East India Company, and that by private individuals: the former is invariably the purest, and *refracts*[3] from three to six per cent., while *Madras private petre refracts* from twenty to thirty per cent.[4], i. e. contains impurities to that extent.

From whatever source it is obtained, the mode

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[1] Rees's Cyclopædia.

[2] Braddock, Memoir on Powder, 1832.

[3] *Refraction* is a technical term implying the amount of impurity.

[4] Brande.

of purification is the same. A quantity of *grough petre* is thrown into a copper of the purest water that can be obtained, in the proportion of about equal parts by weight (28 cwt. of petre to 392 gallons of water[1]); it is then quickly raised to a boiling heat, which is continued from three to five hours, skimming the impurities from the surface as they rise: when sufficiently boiled, the fire is allowed to decrease, and the solution is left for about two hours to cool and subside. It is then pumped or ladled into the filtering trough, provided with wooden cocks opposite to each filtering bag, in order to regulate the supply. The bags are made of closely woven canvass doubled, through which the liquor filters into the carrying pans, the first portions being returned into the filter; it is immediately carried to the crystallizing pans, which are about thirty inches diameter and ten or twelve inches deep, where the solution is left twenty-four hours to cool and crystallize; the pans are then tilted on their edges and placed face to face, to allow the liquid to flow away through troughs into a well. The pans are arranged in parallel rows on stands. The second purification however is precisely similar

[1] Water at 212° dissolves its own weight of nitre.

to the first; except that about 300 gallons of water are used to 30 cwt. of crystals of the first refining.[1] In filtering this solution also, the bags are sometimes doubled, thus making four thicknesses of canvass; and when crystallized, the pans are set on edge, as before, to drain for six hours, or any convenient period. It is sometimes, though very rarely, purified a third time, but it is easily tested by dissolving a few grains in distilled water, and adding a drop or two of nitrate of silver, which is so extremely delicate a test, that it will detect the presence of $\frac{1}{42230}$ part of common salt, or $\frac{1}{108333}$ part of real muriatic acid.[2]

The saltpetre in its *grough* state is mixed with earth, stones, vegetable matter, and various salts, from which it is entirely freed by the simple process of boiling, filtering, and crystallization, being dependent on the various temperatures at which different salts are soluble in water. Nitre is [illegible] more soluble in boiling water than in cold; common salt is not; the solution of nitre is therefore drawn off at a high temperature, [illegible] muriate of soda, having first saturated [illegible] is deposited and left

[1] Braddock. [illegible]cum's Chemistry.

behind in substance. Again, nitrate of lime, the muriates of soda, lime, and some other salts, are more soluble in cold water than nitre: hence the nitre crystallizes while they remain dissolved in the cold liquid menstruum, or mother water. It is on these beautiful natural laws of crystallization that the purification depends.[1]

The liquor which has been poured off the crystals contains a considerable portion of nitre; this is afterwards concentrated by boiling, and then filtered: the saline impurities remain in a solid state, and will not pass the filter; the greater part falls to the bottom of the copper, and is thrown into heaps with the other impurities, and is used for manure.

The saltpetre having been purified and drained, is then melted in a copper, to drive off the water taken up during the crystallization[2]; but this fusion should be effected at as low a temperature as possible (about 500° to 600°), otherwise, if raised to a red heat (1050° to 1207°), a portion of the oxygen of the acid would be driven off, and the saltpetre, or nitrate

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[1] Braddock.

[2] This is not what is called water of crystallization, as nitrate of potash does not contain any, but merely the water enclosed between the crystals.

of potassa, would be converted into a *nitrite* of potassa, highly injurious to the powder in consequence of being a deliquescent salt: this, however, could only happen through extreme carelessness, and may be detected by touching the fused nitre, when cold, with a brush dipped into a strong solution of sulphate or nitrate of copper: if too much heat has been employed, the nitre will turn green where touched; but if in its proper state, no change will be visible.

When completely fused the fire is withdrawn, and the nitre allowed to cool until crystals just begin to shoot round the edge, when it is immediately ladled into copper pans, eight or nine inches deep, and about twelve inches diameter, where it soon consolidates, and is turned out in cakes (weighing from thirty to forty pounds) while hot.

A number of t cakes are taken to the mill, and placed o bed of the trough, which has a cast-iron bot they a then broken to pieces with a large mer, and the mill-stones being put in mo by means of horses, they are crushed which the man who attends keeps t er with a shovel, walking round with s: thus grossly pulverised, in a shor t is removed to the hopper and ground een two horizontal

stones, in the same manner as wheat is converted into flour, passing into a bin in its finished state of an impalpable powder.

The quantity of saltpetre imported into England during the seven years from Christmas 1762 to Christmas 1769, amounted to 247,689 cwt. 3 qrs. 3 lbs., being equal to 3,963,036 lbs. annually.[1] And in the five years, 1826 to 1830 inclusive, 42,790 tons were imported, being an average of 19,169,920 lbs. annually.[2]

In M'Culloch's Dictionary of Commerce the number of tons imported during ten years, ending in 1833, make the average each year upwards of *twenty millions of pounds*.

The charcoal formerly employed in this manufacture was made in the common manner, called charring, in pits: the wood being cut into lengths of about three feet, was piled on the ground in a circular form, from three to four cords of wood [illegible] a *pit*; this being covered with straw, fern, [illegible] kept on by earth and sand to retain the heat [illegible]en fired, was supplied with air by vent-[illegible], at intervals, as found to be necessary. [illegible] this method of charring is extremely [illegible]d uncertain;

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[1] R. Coleman, Esq.

[2] From returns made in [illegible]yal Arsenal, Woolwich.

and no reliance could be placed on charcoal thus made for gunpowder.

The method now adopted is said by some to have been first proposed by the Bishop of St. Asaph[1], and by others the merit is given to Dr. George Fordyce: this is, to distil the wood in cast-iron cylinders, and to collect the tar, pyroligneous acid, &c., allowing all volatile matter to escape into the air, and leaving the charcoal in the retort. The woods preferred for this purpose are the black dog-wood, alder, and willow; but the dog-wood is only used for the best sporting powders, and the other two for Government powder, any wood being employed for the common kinds: indeed, the difference in the quality of the charcoal appears to depend more on the manner in which it is prepared than on the nature of the wood. Braddock observes, that in [illegible] the gram-bush plant (*cytisus cajan*), [illegible]nsonia, and milk-hedge (*euphorbia tiracul[illegible]*re found to answer well. The wood should, [illegible]ever, be carefully freed from the bark and [illegible]ts, for which reason it is usually felled in [illegible]hen the sap is up, and it will peel [illegible]erwise the gunpowder

[1] Bishop Watson, Mem[illegible]i. First adopted in 1783 or 1784, while the Duke of [illegible]mond was Master-General of the Ordnance.

would scintillate in use, and consequently be dangerous: this is rendered very evident by the combustion of charcoal, with and without the bark, in oxygen gas. The wood being cut into billets of convenient lengths, is sorted into various sizes, as the charge of wood for each *pot*, or cylinder, should be nearly of the same diameter, which varies from half an inch to three or four inches; and, of course, the length of time required to convert it into charcoal depends on the thickness.

The cylinders are set horizontally in brick work, each being heated by a separate furnace for the best sorts of charcoal: for the commoner kinds, one furnace only is employed to heat three or four cylinders. At the back of each cylinder there are two pipes, one at the top and another at the bottom, each bending downwards into tubs. When the fires are lighted, the charge of wood is introduced at the front, and the opening perfectly secured by an iron door and bar, well luted round the edges with sand and clay: as soon as the cylinders become red hot, tar flows out at the lower pipe, and pyroligneous acid condenses in the upper tub, while the smoke and vapours escape through a tube. When the smoke ceases, the fire is withdrawn, the front removed, a *scupper* is hooked between the cylinders, and the whole contents

are raked as quickly as possible while red hot into a large cylindrical iron box, which is immediately covered by a lid to exclude the air, and left to cool. From two to four charges may be drawn from each cylinder per day.[1] The charcoal is then ground at the charcoal mill in a similar manner to the saltpetre.

It has been asserted[2], that the difference in the strength of gunpowder made from charcoal thus prepared and common charcoal is so great that the proportion of powder used for the various pieces of ordnance in the army and navy was reduced one third in consequence; but this difference cannot be wholly attributed to the improved method of charring the wood, but in conjunction with other improvements in the manufacture effected about the same time. Charcoal prepared in the common way contains a small portion of alkali (potash), from which the cylinder charcoal appears to be almost entirely free; therefore the advantage of the latter appears to be rather in the preservation of the powder for any length of time, than in the absolute increase of strength when newly made. If, however, the wood has been exposed for a year to the

[1] Pigou and Wilks d... a day. The King's mills at Ballancally in Ireland, ... r ti...s.— R. Wilks, 1835.

[2] Phil. Trans. vol. ix. ...ole...an.

rain and air, the alkali appears to be very nearly removed. Some remarkable instances of the spontaneous ignition of charcoal in store have occurred, which have probably been caused by the accidental formation of pyrophorus from aluminous clay or animal excrement mixing with the wood previous to charring.[1]

The recent fire in the dock-yard at Plymouth (Sept. 27. 1840.) might be easily accounted for, if any quantity of refuse matter of various kinds had been suffered to accumulate in contact with wood or inflammable substances.

Not long since a large woollen manufacturer at Stroud informed me, that in cleaning out the carding machines, a quantity of the woollen dust mixed with emery, oil, and fine iron grindings, being put into casks, was found after some considerable time to give out a smell of burning, and being quite [illegible] it was spread out near the banks of a ca[illegible] but no symptoms of fire were visible: so[illegible] hours afterwards, however, the mass, which [illegible]tended over a considerable surface, and wa[illegible] more than three or four inches thick, be[illegible]ed hot in several places. This effect [illegible]ppear to have been produced by [illegible]ical action called torrefaction, which [illegible]l of fermentation,

[1] Bulletin des [illegible] Militaires. 1831.

but from a cause analogous to that of the action of sea-water on cast-iron, which will be explained hereafter.

Sulphur is generally found in the neighbourhood of volcanoes in large quantities, and is principally imported from Sicily. It is a simple combustible substance, which is stated in most chemical works to begin to evaporate at about 170°, but a minute portion certainly volatilises at a temperature not exceeding 140°, as I have myself scraped it from the walls of the *drying house* at Dartford, where the steam heat never exceeds that point. At 220° it is completely fluid, and at 600° it sublimes, and may be collected in the form of flowers of sulphur, but in this form it is said not to produce such good gunpowder as when fused and ground. The purification is effected merely by melting with as little heat as possible; the lighter impurities rise to the surface and are skimmed off, while the heavier ones sink to the bottom: this operation is repeated if necessary; it is then pulverised in the same way as the other ingredients.

The use of sulphur is not absolutely essential to the formation of a good gunpowder, especially in large charges, for "Mr. Napier directed some powder to be made with nitre and charcoal only, and was surprised to find that 15 lbs. of it

projected a thirteen-inch shell as far as the best powder composed in the usual manner."[1] And the French also found that the projectile force of the powder without sulphur was as considerable as with it, in large charges, but not in small.[2] It appears however, on the whole, to be an important ingredient, as it assists in the preservation of the powder, renders it more compact, and solidifies it in the operations of pressing and granulation, besides more rapidly diffusing the flame through the whole mass, and performing several other important chemical offices: it cannot therefore ever be omitted with advantage or propriety when it can be obtained, and few substances are more abundant.

By experiments made at Essone, near Paris, in 1756, it was ascertained that the strongest mixture without sulphur consisted of sixteen parts nitre and four parts charcoal.[3]

The several ingredients having been thus prepared are sent to the *mixing-house*, and carefully weighed in the proper proportions. The charcoal is first spread in a shallow trough, and the sulphur and saltpetre passed through a large open sieve upon it: the whole composition is then well mixed by the hands and put into bar-

[1] Gray's Operative Chemist, 1828.
[2] Rees's Cyclopædia.
[3] Phil. Trans. vol. [illegible] Coleman's Paper.

rels. This method may appear deficient, but it is amply compensated for in the subsequent process at the *powder-mill*, which is a brick building with a light boarded roof. In the centre is a large circular trough, having a smooth cast-iron, or stone bed: in this trough two mill-stones fixed to an horizontal axis traverse; each stone weighs from three to four tons, and they make seven or eight revolutions in a minute: each stone is followed by a wooden *plough*, attached to the axis, which scrapes the sides of the trough, and keeps the composition under the *runners*. About 40 lbs. of the composition is spread evenly over the surface of the bed, which from its extent is not more than half an inch in thickness: it is slightly moistened with the smallest quantity of water possible to bring it into a proper consistency, but not enough to form it into a paste; and when the *runners* (as the mill-stones are called) have made a sufficient number of revolutions and the composition is in a proper state, it is removed in the form of *mill-cake*. This process is usually performed in three hours at the Government Mills, but varies, according to the state of the atmosphere and the quality of the powder required, from one to six hours. Experienced workmen can alone determine by the appearance of the composition when it has been sufficiently worked to be *alive* or

glide from under the runners, which is the criterion.

Powder makers are not allowed by law to work more than 42 lbs. at the same time in this process, as accidents frequently occur from the stones coming in contact with the bed; but it is seldom that much mischief is done in this state, from the dampness of the composition: this however depends much on the length of time it has been worked; for if it be nearly completed, the roof is blown off, and the sides of the mill thrown outwards to a considerable distance, making what is called a *skeleton*. These mills are generally worked by water or steam power.

The *mill-cake* being broken up and put into tubs, is conveyed to the *press-house*, where it is spread about three inches thick on alternate copper plates until the press is full, when two men work it by means of a powerful screw with capstan and levers seven feet long. After receiving sufficient pressure to consolidate the whole mass, the front of the press is opened, and the *press-cake* taken out in slabs resembling slate, two or three inches thick, and the size of the press. These cakes are broken into small pieces with wooden mallets and wedges, and sent in barrels to the *corning-house*.

In some powder-mills Bramah's hydraulic press is employed, and the composition is much

more forcibly condensed, and in much thinner cakes; but no practical advantage appears to result. Sir William Congreve introduced this plan, and a variety of other alterations, in the manufacture, but, from some cause, they have never been adopted generally: indeed, it appears that gunpowder may be considerably injured by excessive pressure, which renders it too dense to inflame with sufficient rapidity.

At the *corning-house* it is granulated by putting it into sieves, the bottoms of which are made of thick bullocks' hides, prepared like parchment, and perforated with holes about two tenths of an inch in diameter; from twenty to thirty of these sieves are secured to a large frame moving on an excentric axis, or crank of six-inch throw; two pieces of lignum vitæ, six inches diameter and two inches or more in thickness, are placed with the broken *press-cake* in each sieve; the machinery being then put in rapid motion, the discs of lignum vitæ (called *balls*) pressing upon the powder, and striking against the sides of the sieves, force it through the apertures in grains of various sizes on to the floor, from whence it is removed and again sifted through finer sieves of wire, to separate the dust and classify the grain. One man works two sieves at a time, by turning a handle and excentric crank, the sieves being fixed to a

frame which is suspended over a bin by four ropes from the ceiling.

The grains are afterwards *glazed* by friction against each other in barrels, which make about forty revolutions in a minute, and contain about 200 lbs. in each barrel. This operation is performed in about six hours, but varies according to the taste of the purchaser, some markets preferring powder with a very high gloss, and others having it dull.[1] The dust formed by the friction adheres to the sides of the barrel, and is cleaned out afterwards. The object of glazing is to break off the minute asperities of the grains, and to give the powder a more rounded and finished appearance, as well as to preserve it better; but it rather diminishes than increases the strength, when compared with recently made *un*-glazed powder of the same quality.

The next operation is drying. This is effected in various ways at different manufactories, but the safest and best method is decidedly by steam. The *drying-house* is a long building,

[1] The gunpowder intended for the African market is made as bright as silver, by putting a quantity of black lead into the barrel; it is fortunately the worst manufactured, being on a par with the guns, which cost about 8*s*. 6*d*. each, and are esteemed equivalent to one human being, in this disgraceful traffic! At the Cape of Good Hope it is preferred dull, probably in consequence of knowing that the African or shining powder is so very bad.

heated by means of steam-pipes passing in a serpentine direction between racks of copper trays, on which the powder is thinly spread: the heat is gradually raised to about 140° Fah., and gradually suffered to decline, the whole operation being performed in twenty-four hours. Formerly a stove, called a *gloom*, which is still used in some mills, was employed. This is a large cast-iron vessel projecting into one side of a room, and heated from the outside, great care being requisite to prevent accidents, as well as to avoid raising the temperature so high as to partially decompose the powder by roasting off a portion of the sulphur: many accidents have probably occurred from some particles of the powder having fallen on the *gloom*.

When the powder has been dried it is put into barrels, and conveyed to the *dusting-house*, where it is first sifted into grains of different sizes, and then passed through a fine wire or canvass reel, to remove all the dust, which is the last process. The powder is then sent to the packing rooms, where it is packed in barrels, half-barrels, and quarter-barrels, either loosely, in papers, or in canisters, according to the quality, each kind having a distinguishing mark, 100 lbs. weight being the quantity for a whole barrel.

Considering the combustible nature of the

materials, accidents very seldom occur; when they do, it is more frequently in the process at the powder-mill, under the *runners*. On one occasion, at Waltham-Abbey mills, when the powder exploded after having been two hours under the *runners*, the doors and windows of the mills on the opposite side of the stream were forced open *outwards*, and the nails drawn.[1]

A similar effect took place when the Dartford powder-mills blew up, in consequence of an accident in the *packing-house*, in January, 1833. One window, which had been recently fitted in Dartford town, about a mile and a half from the works, was blown outwards into the street, and a considerable quantity of the paper was carried from the packing-rooms as far as Eltham and Lewisham.[2]

The sudden rarefaction of the air may account for this circumstance; the atmospheric pressure being removed in the vicinity, the doors and windows were forced open outwards by the expansive power of the air contained within the buildings in the immediate neighbourhood.

Gunpowder when good should combine quickness of ignition with great projectile force, and

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[1] R. Coleman. [2] R. Wilks, Esq.

capability of resisting, to a certain extent, the moisture of the atmosphere; and there are various methods of proving gunpowder in order to ascertain these qualities; but there is no subject which requires so much practical knowledge and minute attention to the most trivial circumstances.

One daily method adopted by powder makers is to lay out three or four heaps of about two drachms each on a clean copper plate, or on writing paper, at a few inches distance asunder; one of these heaps being fired by a red-hot iron, the goodness is estimated by attending to the following appearances: — if the flame ascend quickly with a smart report, leaving the plate or paper free from specks (called *beads*), and no sparks (called *lights*) fly off, so as to ignite the adjoining parcels, then the purity of the ingredients and proper manipulation may be inferred, but it is only by long experience and due allowance for the state of the weather, that correct inferences can be obtained, as the same powder which burns red and free from beads on a fine clear day, will exhibit a black and moist plate on a damp day, even twelve or more hours previous to rain.

The common wheel eprouvette is also used, but is by no means an instrument to be relied on, as the quantity of powder is very small, and the action

caused merely by the percussion of the flame, and not by its continuous power; it is merely calculated to make comparative experiments at the same time, as it is much influenced by its state of cleanliness, and no two give similar results.

The quadrant eprouvette being free from friction, and the power to be overcome being always the same, is not subject to these inconveniences; the strength of the powder is estimated by the number of pounds avoirdupoise required to close a spring which has a graduated arc attached to it: the little mortar holds ten grains of fine T. S. powder, which I have sometimes found to drive the index to 70 lbs. through a space of three inches.[1]

Various other methods are adopted; for no single plan ever yet devised is sufficient to judge of the goodness of gunpowder. The projectile force is proved by the extreme range of a 68-pounder iron shot from an 8-inch Gomer mortar, laid at an angle of 45°, which, with four ounces of new cannon powder, for government service, must not be less than 380 feet, and with re-stoved powder 350 feet.[2] It is also proved by the gun

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[1] Pigou and Wilks's T. S. Canister, Sept. 1. 1834.

[2] Two ounces of Pigou and Wilks's T. P. L., or cannon powder, from an 8½ inch Gomer mortar at 45° on a solid stone bed, projects a 68-pounder shot, 208 feet. — R. Wilks.

eprouvette, first invented by Dr. Hutton, with a charge of two ounces of powder only, without any wadding or ball; merely poured into the gun after being accurately weighed: the index must describe an arc of 21° with new powder, and not less than 20° 30′ with that which has been re-stoved.

The proof of fine-grained or small-arm powder is with a charge of four drachms from a carbine barrel, to perforate with a steel ball a certain number of half-inch wet elm planks, placed three quarters of an inch asunder, the first being 30 feet from the muzzle of the barrel. T. P. F. propels the ball through fifteen or sixteen boards, and re-stoved, through from nine to twelve.

This powder is also proved by the gun eprouvette with a charge of two ounces, and the arc described should not be less than 26° with new, and 24° with re-stoved and all other descriptions of fine powder.

Another trial is to expose one pound of each sort, very carefully weighed, in a room without fire for two or three weeks, during which time, if the materials be pure, the increase of weight by the absorption of moisture from the atmosphere should not exceed one per cent.

In all experiments with gunpowder, it is essential to proportion the size of the grain to the quantity employed for each charge; for if

equal weights of the same powder, differing only in the size of the grain, be tried against each other on a large scale of several pounds, the large grain will almost invariably project a ball farther than the fine; while, on the contrary, in charges of only a few drachms or ounces, the fine grain always beats the large. Inattention to this circumstance has often led to opposite opinions respecting the relative advantages of large and small grain; which, in fact, depend entirely on the scale of the experiment: and the reason appears to be that the flame cannot readily penetrate large masses, if in a very compact state, with sufficient rapidity to inflame the whole at once, but drives out some portion unignited; whereas if the size of the grain be *in proportion to its quantity*, the interstices admit of a free passage.[1] For this reason, the grain ought to be much larger for mortars than for cannon having longer bores, as the powder in the former requires to be lighted instantaneously, or a portion of it must be blown out unignited, whereas in the longer guns there is sufficient time for the perfect combustion of the whole.

[1] A writer in the *Bulletin des Sciences Militaires* spends twenty-eight closely printed pages to prove that small grain should always be employed.—Braddock.

The projectile force of gunpowder depends on the instantaneous conversion of the solid materials into a permanently elastic fluid, which is at the same time greatly increased in volume by the intensity of the heat (which I have experimentally found, even on a very small scale, sufficient to melt copper instantly). Now it has been ascertained that one cubic inch of gunpowder is converted into 250 cubic inches of permanent gases when cooled down to the temperature of the atmosphere; and Dr. Hutton has calculated that the increase of volume at the moment of ignition cannot be less than eight times: therefore a cubic inch of gunpowder at the time of explosion, if confined, exerts a pressure of at least 2000 lbs. on the square inch, in every direction, which may at once account for its extraordinary power.

Various methods have been proposed to analyse gunpowder, but the simplest and best is the following:—100 grains, very accurately weighed, or any definite quantity, should be first carefully dried in a moderate heat, reduced to a fine powder in a porcelain mortar, and put into a phial about three parts full of distilled water and boiled; it must then be poured into a filter of bibulous paper, which has been previously dried and weighed, and fresh portions of distilled water must be poured

through, until no trace of saltpetre remains, which can be detected by the taste: the quantity of saltpetre is ascertained by evaporation and drying with great care. The filter containing the sulphur and charcoal must be dried slowly at a heat that will not sublime any portion of the sulphur, and weighed altogether while hot: the powder must be carefully removed with a spatula, and put into a phial. A solution of caustic potash filtered, and equal in strength to 5° of Beaumé's Aréometre, should be divided into three portions; the first portion to be poured on the residue in the phial, boiled for some time, then turned into the filtering paper, previously dried and washed as before, and an intensely golden yellow liquor passes through: the second and third portions of the solution of potash are to be poured, boiling hot, over the residue in the filter; the last, and sometimes the second, are perfectly colourless, having removed all the sulphur: finally, wash the filter with distilled water, dry carefully, and weigh while hot; deduct the known weight of the filter, and the weight of the charcoal is obtained; this, added to the weight of saltpetre already ascertained, shows the amount of sulphur; and if the total weight be the same as the original quantity, the analysis is of course correct.

The gases resulting from the explosion of powder are principally carbonic acid gas and azote, with a very small portion of sulphuretted hydrogen and sulphurous acid gases; the latter may be removed by washing. The presence of sulphuretted hydrogen may be tested with paper dipped in a solution of acetate of lead, and removed by washing with about an ounce of chloride of lime or soda: the residuary gas will be nearly all carbonic acid, which may be tested with lime-water.

That portion of the powder which is not converted into gas, but remains in a solid state after the explosion, consists of potash combined with sulphuret of potash and unconsumed charcoal. This residuum is very deliquescent, attracting sufficient moisture, when exposed to the air, to dissolve the alkali and expose the charcoal: indeed, the chemical action of this residue is so great, that if collected in a quantity of a few ounces, considerable heat is evolved. Mr. Richard Wilks, after repeatedly firing a mortar, obtained about two ounces, which he put into a tin vessel, and twenty-four hours afterwards found it too hot to hold in his hand.

The effect produced by gunpowder on metals in long continued rapid firing is very extraordinary. Several of the guns employed at the siege of San Sebastian, and sent into the arsenal

at Woolwich as unserviceable, were cut open, and the interior of some of the vent-holes, which were originally cylindrical, and only two tenths of an inch in diameter, were enlarged, in a curious and irregular manner, from *three to five inches* in one direction, and from *two to three inches* in another; but the brass guns[1] were much more affected than the iron. In consequence of this, some experiments were ordered to be made in order to ascertain the difference of effect produced on different metals, and 400 rounds were fired from three 24-pounders as quickly as possible: in one the vent-hole was drilled in the solid cast-iron of the gun itself; in another, a bolt of wrought iron was first screwed in, and the vent-hole drilled through the centre of it; the third had a bolt of pure copper, through which the vent-hole was drilled. After the firing, the cast-iron vent was cut out of the solid metal, and found to be very much injured and enlarged; the wrought iron was but little damaged; and the pure copper was scarcely altered in form; thus establishing the fact, that pure copper is the best material for the vents of heavy ordnance.

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[1] Gun metal is an alloy of copper and tin, but these guns are usually denominated "*brass guns.*"

Attempts have been made by the French at various times to manufacture gunpowder with the chlorate of potassa instead of the nitrate, but one made at Essone in 1786, at the suggestion of Berthollet [1], was attended with the most serious consequences and they were compelled to abandon it; since which (in 1811) it is said that they succeeded in making powder with it, which produced nearly double the range of ordinary powder. [2] It is, however, far too dangerous a composition to employ on a large scale, and rapidly destroys the chamber of the gun, therefore is never likely to be introduced into actual service.

At the close of the preceding article on guns, I have alluded to the fact of common gunpowder, in the usual proportions, being capable,

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[1] Annales de Chimie, tom xi. p. 22.

[2] Bibliothèque Physico-Economique, tom. ii. p. 83.; and Traité de l'Art de fabriquer la Poudre-à-canon, par MM. Bottée et Riffault. Paris, 1811. 4to. p. 330.

The formula given is as follows: —

Chlorate of Potassa - - -	0·450
Nitrate of Potassa - - -	0·250
Sulphur - - - -	0·150
Alder wood filings, passed through a silk sieve - - - -	0·075
Lycopodium - - - -	0·075

Mixed with about 30 per cent. of water holding in solution 0·01 of gum Arabic.

by peculiar manipulation, of becoming fulminating powder; but ordinary gunpowder will explode with a very sharp blow of a hammer on an anvil.

There are some curious facts connected with the action of various fulminating powders on gunpowder. I have already described the experiment made to illustrate the passage of flame through gunpowder without igniting it, when speaking of the breechings of fowling-pieces at p. 80. I may here add another experiment.—If a train of gunpowder be crossed at right angles by a train of fulminating mercury laid on a sheet of paper, on a table, and the gunpowder be lighted by a red-hot wire, the flame will run on until it meets the cross train of fulminating powder, when the inflammation of the latter will be so instantaneous, as to cut off the connection with the continuous train of gunpowder, and form a T, leaving one half of the gunpowder train unignited. If on the contrary, the fulminating powder be lighted first, it will go straight on, and pass through the train of gunpowder so rapidly as not to inflame it at all. The description of the manufacturing processes is from my own observation, at the extensive powder mills of Messrs. Pigou and Wilks at Dartford, to which I have always had access; and should the method described differ from others, it is certain that no practical advan-

tage can be obtained by such deviation, because better powder has never yet been made than at the mills to which I have alluded.

Those who wish to obtain the best practical information on gunpowder that has hitherto been published, should consult Mr. John Braddock's "Memoir on Gunpowder" (1832), a small work which I have often quoted, and which contains a greater number of facts on this subject, than any book I have ever met with; it is particularly interesting in relation to the manufacture of gunpowder in India, having been originally printed at Madras in 1830. Brewster's Encyclopædia, and the Supplement to the Encyclopædia Britannica, will also be found to contain valuable articles on this subject.

PART VII.

ON SWORDS, BRONZE AND IRON; AND ON THE CAUSE OF THE PATTERN, OR WATERING OF THE DAMASCUS BLADES.

THE antiquity of swords, either of wood or of metals, is well known, and the employment of them by every nation engaged in warfare rendered this weapon a subject of much greater importance formerly, than it is at present, if we may judge by the perfect indifference generally manifested as to their quality.[1]

It is extremely probable that wooden swords were in use long before the working in metals was understood, as the transition from a club, or the branch of a tree, to a piece of wood fashioned with a cutting edge, is very trifling, and might naturally suggest itself to the minds of savages: indeed we find that the Mexicans were armed with wooden swords, when first discovered by the Spaniards, and wooden swords are still common among uncivilised people.

Copper swords have been found in Ireland,

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[1] Officers are not unfrequently supplied with this weapon by their tailors.

but a worse material could hardly be conceived—much inferior to wood, or to the iron ones of the Gauls, which, according to Polybius, were obliged to be straightened under the feet after having exchanged a few blows.[1]

It is certain, however, that in former ages, swords were so highly valued as to be kept in temples, and bequeathed in the wills of princes and warriors. They were also distinguished by proper names, descriptive of their supposed qualities, or alluding to their destructive powers; a method borrowed from the Arabians and Persians, practised by Mahomet, and continued to the present day in the East.

We naturally look to Egypt as the source from whence we expect to derive the earliest knowledge of arts and manufactures; and as this subject may possibly be rendered more interesting by a brief statement of the general conclusions drawn from a careful investigation of the most authentic ancient and modern authors, we must refer in the first place to the Sacred Writings, as the oldest records.

In Genesis iv. 22., Tubal-cain is stated to have been "an instructor of every artificer in

[1] Polybius says that in the year 222 B. C., an army of Insubrian Gauls entered the North of Italy, and were defeated by the Romans chiefly from this circumstance.

brass and iron." The Hebrew word Barzel (בַּרְזֶל), which is uniformly rendered iron, would infer that the Egyptians were from the earliest times acquainted with this metal, but no trace of it has ever been discovered in the excavations that have been made, which is extremely singular if it was generally used; as swords, vases, tables, carpenter's tools, pins, and every other article in daily use, have been discovered in bronze or an alloy of copper, but not a vestige of iron. If we suppose that the Egyptians employed tools made of steel to carve their hieroglyphics on obelisks and temples of granite, or syenite and porphyry, there can be no doubt that it was obtained at great cost from the south of India, and therefore rarely used. A maritime intercourse was maintained from the remotest antiquity, between the Malabar coast, the Persian gulf, the country about the mouths of the Indus and the Red Sea; and it appears reasonable to conclude, that the steel of the south of India found its way by these routes to the nations of Europe, and to Egypt; but the cost of transporting it would render it extremely rare, as the present of about thirty pounds of steel, made by Porus, an Indian chief, to Alexander of Macedon[1], sufficiently proves.

[1] Quintus Curtius.

It has generally been considered that carving on hard stones could not be executed without employing steel, but even diamonds and gems are cut with soft metals and their own dust or powder; therefore, I am inclined to think that bronze would be capable of effecting sculpture like theirs, aided by *time* and *patience;* the former being of as little value in those days, as the latter is rare in our own. All our manufactures and movements are now so rapid, that we are scarcely competent to imagine what may be effected by the combined powers of numbers and time.[1]

Admitting that they were acquainted with iron, they would not be likely to employ it for cutting instruments, being softer than bronze, unless we also grant that they either understood the art of converting it into steel, as well as of tempering it, or that they obtained it in the state of *wootz*, or cast steel, as prepared in India; which does not appear probable, as there is no Hebrew word for steel, unless by the expression "*Northern* iron," (which means *Eastern*,) steel was included. In Jeremiah xv. 12. the passage "shall iron break the *Northern* iron and the *steel*," has been incorrectly rendered in our version, as well

[1] The reasons for this supposition will be seen in treating of the alloys.

as in many other parts where steel is mentioned; the Hebrew words being *Barzel* and *Nehhosheth* (נְחֹשֶׁת וּבַרְזֶל), or iron and bronze; as we find the same passages translated in the French Bible by Le Maistre de Sacy "*de l'airain et du fer.*" Another question also arises as to the meaning of *Northern* iron: for previous to the conquest of Babylon, the Jews were acquainted with two kinds of iron; namely, that in common use, and a very superior kind called Northern iron, which might seem to allude to the celebrated iron or steel manufactured by the Chalybes, a people who lived on the southern shore of the Black Sea, and nearly due north of Palestine; but on close investigation this does not appear to be the case, but that we must look to the east of Babylonia for the place where the iron or steel was prepared. The sacred historians were not required to possess correct geographical or scientific information; nor was it probably ever intended that knowledge should be otherwise than progressive. Their records, purely relating to religious events, should and must ever be received implicitly and reverentially; and if they err on other subjects, it is simply because they adopted the opinions and ideas of the age in which they lived. There are maps still in existence in which errors of equal magnitude are

distinctly laid down; therefore it is not surprising that at more remote periods, the relative geographical position of one country to another should not be correctly known.

In Isaiah the word north appears to be used as synonymous with the rising of the sun.[1] The impending invasion of the king of Babylon is called danger from the North[2]; and the destruction of Babylon itself by the Medes and Persians, nations inhabiting due east of that city, is described by the expression, "a nation from the north shall make her desolate."[3]

It is therefore probable that the only iron or steel they were acquainted with, came in the way of commerce from India. It can be proved that the Greeks continued to prefer and to employ bronze for a long period after the art of tempering steel was known to them, their knowledge of bronze being undoubtedly derived from the Egyptians. Pliny[4], quoting Hesiod, says that the knowledge of iron was brought over from Phrygia to Greece by the Dactyli, who settled in Crete during the reign of Minos I., about 1431 B. C.; yet, during the Trojan war, 200 years after that

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[1] Isaiah, xli. 25.

[2] Jeremiah, i. 14. "Out of the North an evil shall break forth."

[3] Jeremiah, l. 3. 9. 41.

[4] Lib. vii. c. 57.

period, iron was in such estimation, that Achilles proposed a ball of it as one of the prizes during the games he exhibited in honour of Patroclus. Now, if the Greeks in two hundred years had made so little progress in an art they learned from others, how long must it have taken the Egyptians, Phrygians, Chalybes, or whatever nation first discovered the art of working iron, to have made that progress which they are represented to have done in the time of Moses? Discoveries are often accidental, but the manufacture of steel, as practised from time immemorial in India, could hardly have been arrived at otherwise than progressively; and there is no evidence to show that any of the nations of antiquity besides the Hindús were acquainted with the art.

But to proceed with this inquiry: — it appears that the iron mines of Spain have been worked at least ever since the time of the Jewish kings of the race of David to the present day, first by the Tyrians, next by the Carthaginians, then by the Romans, and lastly by the natives of the country; that a trade in iron or steel of the best quality, manufactured in the remote East, and conveyed by land carriage to Syria, existed at the same early period, and continued at least as late as the first century of the Christian æra; that the Greeks in the most early times, though acquainted with the use of iron, and perhaps of steel, did

not employ it for offensive weapons, preferring bronze; that after what are called the heroic ages of Greece, the use of bronze was superseded by iron or by steel obtained from the Chalybes on the Black Sea; that there is no evidence of the Romans, even in the earliest times, having used for offensive arms any material except iron and steel; that the iron mines of Elba were worked at least as early as the time of Alexander of Macedon, and that afterwards the Romans obtained iron from Spain and from Styria.

But a discovery has been made in later days, which proves that in some parts of Italy, at least, the use of bronze for cutting instruments, for articles of furniture, and for domestic use, was continued to a late period. From Pompeii and Herculaneum, those mines of undoubted antiquity, have been obtained all sorts of articles in metals and stone that were used by the inhabitants of those towns. Some few are of iron, but by far the greater number are of bronze. Instruments of iron might have been destroyed by their long sepulture of seventeen centuries; but if they ever existed, the wonder still remains how bronze and iron should be considered equally applicable to the same purposes.

In all the Latin writers *ferrum*, iron, is the common name of a sword. Whether is this word derived from *ferrum*, iron, or from *ferire*,

to work er would be equally applicable to swords of every material? The swords that have been found in these towns are of bronze, as well as the points of spears; pole-axes and even surgical instruments, forty in number, have been discovered, some with cutting edges, but all of bronze. There is no reason to suppose that the towns of Pompeii and Herculaneum were peculiar in this respect; therefore it is extremely probable that the inhabitants of the South of Italy, in their customs and practices, even so late as the first century, presented in their use of bronze a faithful representation of the Homeric age.

It becomes an interesting inquiry, then, to ascertain the capabilities of bronze to perform all the varied operations required by the ancients: and it may not be improper to observe, that the word *brass* has been very commonly used by antiquarians and others, instead of bronze, which only leads to confusion, and ought to be avoided; bronze being an alloy of copper and tin; brass a compound of copper and zinc.

In order to ascertain this point experimentally, I commenced some experiments in conjunction with my friend Mr. Arthur Aikin, to whom I am much indebted for historical information on this subject; and the result of these experiments may probably be useful to others.

Having procured some very pure Swedish copper and fine grain tin, we had several ingots prepared by a very careful and experienced caster, in the following proportions :—

Alloy, No. 1., or ancient soft bronze, according to Pliny[1] — 9 parts copper and 1 tin.

This alloy, when hammered cold to the utmost it was capable of bearing without cracking, bore tolerably well an obtuse or *cold chisel* edge, which would cut ordinary brass, but required frequent sharpening on a close-grained stone. It might form the matrix of a die, and could be easily cut with a chisel formed of the

Alloy, No. 2., or ancient hard bronze, according to the same author :— 7 parts copper and 1 part tin : which, well hammered, bore an edge fine enough to mend a quill pen with some little difficulty and frequent sharpening : it is however the most generally useful alloy, as it makes good chisels for wood, and punches which may be used for die sinking in alloy, No. 1. Swords, knives, and even springs might be made of it, and in the absence of steel be considered good.

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[1] Pliny, lxxxiv. c. 10.

No. 3. Experimental alloy: — 8 parts copper and 1 part tin; it was harder than either No. 1. or No. 2.; broke sooner under the hammer, required more care to work, and appeared to be rather harder than soft-cast steel, but as difficult to file as spring-tempered steel when well hammered.

Sir Francis Chantry formed an alloy of 16 parts copper, $2\frac{1}{2}$ tin, and $2\frac{1}{2}$ zinc, from which he had a razor made, and I believe shaved with it. Mr. Aikin wishing to try the nearest proportions to this, according to the theory of atoms, a compound alloy was formed:—

No. 4. Experimental—120 atoms = 3792 copper.
10 ditto = 589 tin.
10 ditto = 646 zinc.

This is as hard as tempered steel; tolerably good razors and penknives might be made of it if we were unacquainted with steel; but it is brittle and quite unfit for instruments requiring toughness or elasticity: it will not bear so acute an edge as steel to stand long, and is malleable only in a slight degree: it soon spoils new files, and no others will touch it. Other proportions were tried, but the result is not worth recording. The general observations to make on these alloys are, that not any of them are malleable at a red or white heat; they are most so, when cold. Con-

siderable elasticity is communicated by hammering Nos. 1, 2, and 3., but mostly to No. 2., which might form swords capable of performing many of the exploits described by Homer, when opposed to no harder substance than themselves.

Homer's forges were probably furnaces for melting, in order to cast into the forms most convenient for working, and tempering would consist in making red hot, cooling slowly, and then hammering when cold as much as the alloy would bear without cracking.

There is one passage in Homer which clearly establishes the fact, that the Greeks were acquainted with the method of tempering steel according to our modern notions. In the Odyssey[1] he uses the following simile, which, literally translated is, "as some smith plunges into cold water a loudly-hissing great hatchet or adze, tempering it, for hence is the strength of iron." Cowper thus translates it: —

> "As when the smith (an hatchet or large axe
> Tempering) immerges all the hissing blade
> Deep in cold water, whence the strength of iron."

This is very decisive, as *iron* treated in this way

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[1] Odyssey, book ix. Cowper's translation. Pope is seldom literal.

would not be tempered or improved in quality; it must therefore have been *steel*, no doubt similar to the *wootz* of India prepared by a process hereafter to be described. Homer rarely mentions iron: he calls the Greeks by the general epithet *brass-coated;* the word translated by Pope, *smith*, is in the original χαλκεὺς, *worker in bronze;* and even when the material employed was iron (σίδηρος), he is called the same, *a brazier*, proving that the two trades were then identical.

Turning our attention to another part of the world, we find no mention made of bronze whatever, which probably was less known to Oriental nations than steel was to the ancient Greeks, and never employed by them for cutting instruments.

It is well known that Damascus was formerly celebrated all over the world for its manufacture of sword blades; and it is recorded, that when Timúr Lung conquered Syria, in the beginning of the fourteenth century, he carried off all the manufacturers of steel into Persia; since which period, the fabrication of arms has declined at Damascus, and the successors of those workmen, being dispersed over the East, are said either to have lost the secret, or ceased to make blades of more than ordinary goodness. We must, however, first divest ourselves of all prejudice

in favour of the exaggerated reports of their qualities, and remember that, at the time when the natives of the East were well acquainted with the art of working in iron and steel, we, and indeed all Europe, appear to have been comparatively in a state of perfect ignorance; the ancient swords of Damascus, therefore, when opposed to those of other countries, were probably found to be infinitely superior in temper and quality; which, combined with their great external beauty, stamped them for ages with so high a character for excellence, that they are even now handed down as heir-looms by Eastern princes to their posterity. The extraordinary prices[1] that have been offered and obtained for them, sufficiently attest the estimation in which they were held, which is certainly not warranted in the present day, when swords of equal or superior quality might be manufactured at one-twentieth the expense. In addition to the foregoing observations, the strength and great dexterity of the swordsmen must be taken into consideration, and much of

[1] Two swords presented to Sir John Campbell by the Shah of Persia, were valued at 200 ducats each, or about 86*l*. And the Umeer of Scind had a large sword, for which he refused 9000 rupees, equal to 900*l*. Sir Gore Ouseley, Bart., has several swords, some of which were valued even higher.

the apparent superiority of these blades may be undoubtedly ascribed to this cause.

The attempt to imitate them has, however, occupied the attention of philosophers and manufacturers in various countries, and at different periods; but these attempts have been mostly directed to produce the external appearance, rather than to attain any superior quality, for which the original swords were famed, and the explanation of the true cause of the watering, or *Jowher* (which, in my opinion, has never been successfully imitated by mechanical means), is still a desideratum. With this view, I attentively pursued the subject for several years, and finally came to the conclusion that the natives of the East are either perfectly ignorant of the cause themselves, or, finding their labours so highly appreciated, have mystified the process as much as possible, in order to avoid the discovery of having no secret to keep.

With respect to the various attempts at imitation, the least ingenious one is certainly that of etching, or engraving, a blade of common steel, merely to deceive the purchaser. Amongst the numerous failures, we may enumerate those of Messrs. Nicholson, O'Reilly, Wilde, and others in England, as well as that of Monsieur Clouet, in France, whose treatise, entitled *Art de fabriquer les Lames figurées, dites Lames de*

Damas, does not contain any method capable either of imitating the figure or the boasted qualities of the real blades; which is clearly demonstrated by Signor Crivelli, in a memorial published at Milan, in 1821, *Sull' Arte di fabricare le Sciabole di Damasco*, in which the author considers that he has discovered the great secret; but, although his method is extremely ingenious, and, in my opinion, calculated to produce swords of great beauty, and equal to any ever made at Damascus, yet I think I may be able to prove that his conclusions are erroneous, and that he has mistaken a natural appearance for an artificial one. Another method, adopted in ignorance of the true cause, or merely for the sake of ornament, is not uncommonly met with in Georgian swords and daggers, and in those of other countries; a central line is formed along the blade, made by a process similar to that employed for the manufacture of gun-barrels in India, and now well known in Europe, consisting of alternate laminæ of iron and steel, welded together, and twisted in a spiral direction: this arrangement is, however, totally different from that of the true Damascus, and wholly unfit for the edge of any cutting instrument, being incapable of producing uniformity of temper. A few celebrated swords made by Goork of Teflis, almost all of which are at present

in the possession of kings, are made of Georgian steel, the ore being obtained from the Siberian mines; they have a broad band of this kind of artificial Damascus near the back of the blade. One of them I have lately examined, and do not consider it superior to the best of our own make, in respect to its useful qualities; the band being merely an ornamental introduction.

The conviction in my own mind that secrets of importance in manufactures can rarely be kept for centuries, induced me to seek for the cause in the material employed; and I think that in China, and other places, where the natives excel in the production of any particular article of commerce, we must generally attribute it to the quality of the material, and the method of manipulation, rather than to the superior skill and knowledge of the workmen. Unavoidable results are often obtained, depending on circumstances unknown to themselves, and, therefore, easily preserved from the curiosity of others.

The *Jowher*, or watering, of the genuine Damascus sabres, I conceive to have been originally produced by two principal causes: first, the nature of the iron-ore; secondly, the method of converting it into steel. The latter differs in various provinces of India, but is essen-

tially the same in all, as I find by the MSS. of Dr. Moorcroft, and Major James Franklin, and also by other documents.[1] The furnace is of a rude description, being composed of stones and mud, or clay; the iron-ore is reduced to a coarse powder; the furnace being filled with charcoal[2], the fire is urged by two bellows, each made of a single goat's skin, until no moisture is given out; a small basketful of the ore is then poured in at the top, and a larger basketful of charcoal, and so on alternately. The scoria begins to run in about an hour, but no flux is employed; the bellows are incessantly worked by men relieving

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[1] In vol. i. p. 245. of the Journal of the Asiatic Society of Bengal, there are some interesting particulars relative to the native manufacture of steel in Southern India, extracted from the MS. Journals of the late Dr. Voysey; and at page 253. of the same Journal, some observations are made on the Salem Iron-works. Dr. Heyne has published his "Tracts on India," in which he fully describes the method of manufacturing iron and steel in various parts of India. The MSS. of Dr. Moorcroft and Major James Franklin are in the library at the East India House. See also Journ. of the Royal Asiatic Society, No. x. p. 390., "On Indian Iron and Steel," by J. M. Heath, Esq.; and Dr. Buchanan's "Travels in the South of India," 1807, contain a very minute and correct account of the native processes of smelting iron and converting it into steel, illustrated by engravings.

[2] Bamboo-charcoal is said to be preferred, probably in consequence of the quantity of silica it contains, which acts as a flux.

each other, and in about six hours the process is finished. The crude iron thus obtained has never been really melted, but falls by its weight to the bottom of the furnace, where the grains agglutinate: in this state it is often malleable. The wall of the furnace is broken down, the red-hot mass dragged out, and divided into pieces, which are sold to the blacksmiths, and forged into small bars. To convert this iron into steel, the bars just described are cut into small pieces, in order to pack them closely in the crucibles; and from half a pound to two pounds of these pieces are put into each crucible with one tenth part by weight of dried wood chopped small; the wood and iron are then covered over with one or two green leaves, and the mouth of the crucible is filled up by a handful of tempered clay, which is rammed in close to exclude the air perfectly.

The wood, which is always selected for this purpose, is the *Cassia auriculata*, and the leaves used to cover the iron and wood are those of the *Asclepias gigantea*, or, when that is not to be procured, those of the *Convolvulus laurifolia*. As soon as the clay, used to stop the mouths of the crucibles, is dry, they are built up in the form of an arch, with their bottoms inwards, in a small furnace urged by two goat-skin bellows: charcoal is heaped over them, and the blast kept

up without intermission for about two hours and a half, when it is stopped, and the process is considered complete: the furnace contains from twenty to twenty-four crucibles.

The crucibles are then removed from the furnace and allowed to cool, and the steel is found at the bottom; but some of the crucibles contain part iron and part steel, others have cracked, and allowed the metal to flow out. The cakes of steel are called *wootz*. They differ materially in quality, according to the nature of the ore, but are generally very good steel[1], and are sent into Persia and Turkey, where such as are suitable for the purpose, are manufactured into sword-blades, razors, and other articles of cutlery.

The cakes of steel are annealed, previous to working them, in a charcoal fire, by keeping them for several hours nearly at the point of fusion, otherwise they would not stand the oper-

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[1] I gave a specimen of Salem steel to an experienced forger, who attempted to work it at various heats without success, and at length declared it to be incorrigibly bad, and perfectly useless for any purpose. I then tried another portion of the same steel myself, and found it could be worked with little more difficulty than ordinary cast-steel; thus proving that, in experiments of this nature, we should never be satisfied with the opinion of one person only, however skilful. These cakes, however, appear to differ very much in quality, and are decidedly inferior to the Cutch steel.

ation of drawing into bars; an excess of carbon being necessary, in the first instance, to insure perfect fusion in the crucibles, which is driven off by the subsequent process.

This is the kind of steel that has always been employed for those blades so celebrated for their beauty; and I consider that it would be as impossible to forge a sword-blade out of some of these materials, when properly selected, without obtaining the true Damascus figure, as it would be to imitate that pattern by any contortions of iron or steel artificially. These cakes of steel are evidently crystallized, and the future pattern of the sword-blades depends on the size and arrangement of the crystals, modified by so many circumstances, that it is not surprising the proper kind of steel for this purpose should be so rare, or that the secret should have been supposed to be lost. Some of the causes which influence the arrangement, are, minute portions of the earths or their metallic bases entering into chemical combination with the steel; the alloy of other metals contained in the ore; the quantity of carbon absorbed by the iron in its conversion; the weight of metal fused at one time; the quickness or slowness of the cooling, which in all cases affects the laws of crystallization, and in some cases even alters the properties of the crystals themselves; above all, it is highly pro-

bable that electrical action may induce a peculiar arrangement of the crystalline structure, according to the temperature; but from whatever cause or combination of circumstances it may arise, it may be rendered self-evident that the figure or pattern, so long sought after, exists in the cakes of *wootz*, or native steel of India, and only requires to be produced by the action of diluted acids.[1]

In the examination of various specimens of *wootz*, I found one large cake, about 2½ lbs. weight, from Cutch, which, on cutting and working, not only furnished excellent steel,

[1] Sulphuric or nitric acid very much diluted with water may be used for this purpose; but immersion in a bath composed of a solution of sulphate of copper in water, in the proportion of one ounce to a quart, produces a better effect, and exhibits the crystalline arrangement perfectly: this is however only calculated for experimental purposes, and not for sword blades; although it succeeds perfectly for artificial specimens of Damascus iron, such as gun-barrels. The surface of the metal must be previously freed from grease, either by rubbing with wood-ashes and water, as in India, or by smearing it over with a paste of chalk and water, and allowing it to dry on; the time of immersion may vary from ten minutes to half an hour.

The Turks employ a paste made of alum and water, with which they cover the blade, and then expose it to a moderate heat. The paste is washed off with water, and the blade is then of a dull lead colour; polishing with oil until the desired effect is produced, and exposure to the sun, complete their process.

capable of being hardened and tempered without much difficulty, but exhibited the Damascus figure, both in the cake itself, and when drawn out by the hammer into a bar; I also found that this bar could be doubled down on itself four times while red-hot, and then welded perfectly together. Several specimens from Salem, weighing about one pound each, have only slight indications of a pattern, the crystals being very small, and the steel inferior in quality. Now, it is a singular coincidence that the trade between Cutch and Damascus was formerly direct; it is therefore highly probable that the ancient blades were originally made of this steel, and consequently, by mere accidental circumstances, presented a beautiful figure; whereas, if the trade to Damascus had been from any other part of India, where the steel was procured from a different kind of ore, or in smaller cakes, or, in fact, did not contain the pattern within itself, the Syrian workmen might never have become more celebrated for the manufacture of their blades than any other Eastern artisans. I find, also, that there are two distinct patterns in the Cutch steel I have examined; one can be produced in a few minutes by the action of dilute nitric and sulphuric acids, which show the general arrangement of the crystals in the cake, and their elongation into lines when drawn into a bar;

but there is a secondary pattern more complicated, resembling the dark lines in the genuine Damascus, which is much more difficult to bring out, and requires the Oriental mode, or the long-continued action of light acids to render it perfectly evident; this appears to result from the lines formed by the currents of the fluid mass of metal while cooling, which currents are well known to exist in all fluids when acted upon by increase or decrease of temperature; in the present instance, the portion of the melted steel which is in contact with the sides of the crucible, is cooled faster than the centre, and falls by its superior density, while fresh portions flowing from the centre to the sides, keep up a continuous circulation until the whole mass solidifies; hence arises the radiated appearance on the surface of the cakes of *wootz*, and hence results the more elaborate pattern, or watering, wholly independent of that formed by the elongation of the crystals themselves.

In all our manufacturing processes, immediate results are demanded, and the effects produced differ considerably from those obtained by the more tedious operations of the East, where time and human labour are less esteemed; this may in some measure account for the doubt and difficulty that has attended the investigation of this subject. It is proper, however, to observe,

that Dr. Faraday and the late Mr. Stodart made several experiments on *wootz*, and it was not likely that so accurate an observer as Dr. Faraday would fail to discover the pattern in the cakes, and trace it to the true cause; but as his experiments were directed rather to ascertain the properties of the steel itself, than to account for the beauty of the finest Oriental blades, the perfect identity between them and the pattern discovered in the Indian steel was still unexplained. It is clear, however, that, independently of the same germ being discernible in the steel itself, we must remember, that one of these cakes is insufficient to make a sword-blade; every blade must be composed of three at least; a heavy blade would probably require eight, or more, depending on the size and the skill of the forger, as the cakes seldom exceed two pounds in weight. These cakes, being first drawn into bars, must be welded together, thus forming laminæ by necessity, and not by choice originally; and as the workmen could not fail to discover that, by increasing the number of laminæ, the beauty and the quality of the blade would be improved proportionally, they had only to double the complex bar on itself, and weld again; and thus, by repeating the operation, increase the number of laminæ at pleasure. Now, it seems evident, that the reason why the

steel in India is made in small lumps instead of larger masses is, that larger and more perfect furnaces would be required in t[illegible]t instance, and then, for want of powerful [illegible]inery, the steel could not be drawn out, or [illegible]nto bars; it would not, therefore, be a [illegible]etable commodity in countries where m[illegible] labour only is employed.

Having forged the blade fi[illegible] such a bar as that before described, the la[illegible], or plates, must necessarily be very thi[illegible]in the process of grinding and polishing [illegible]k into each other; the indentations of the hammer, and the clumsiness of the forger even combining to increase the diversity of figure, thus completing all those variegations of pattern so eagerly sought after in every country, and for many centuries.

One illustration, in conclusion, may suffice; if we examine any mass of crystals, such as fluor-spar, for example, one surface of which is polished, we shall perceive all the pattern and indications of its crystalline structure. Let us now suppose such a mass to be drawn out to a considerable length, as in forging; the crystals become spread and elongated into delicate tortuous lines, spreading over and throughout the whole substance; and by the union of several such bars, unequally cut through in various

parts, we may, I think, imagine all the variety required to fulfil the condition of my argument, which is, that the figure of the genuine ancient and modern Damascus sword-blades *is the result of nature, and not of art.*[1]

About [illegible] years since, General Tchefkine presented [illegible] a blade made from the Siberian iron ore [illegible] into steel at Petersburg and manufactured [illegible], which perfectly corroborated my opinion previously published in the Journal of the Royal Asiatic Society. The same gentleman (with the Director-General of the mines) returned to England again this year (1840), and brought with him several sword and dagger blades manufactured altogether in Russia from cast steel, which were fully equal in beauty to the finest Oriental blades I ever saw, and far exceeded them in the elegance of the gold ornamental part, thus fully establishing the truth of my assertion, as the pattern in these blades was

[1] The Oriental blades are distinguished by names, which indicate their quality; those in which the lines are as fine as the hair of the Angora goat, being most esteemed. The Kara Khorassan and Taban are of the first quality: the former is supposed, in Persia, to have been first made in the reign of Ismael Shah, from small square cakes of steel, sent from the mines in Golconda, which are said to be exhausted, as none of this steel is now sent from there to Persia. The second quality is the Ilankavy and the Kakmerduen; the third, the Kara and the Tertz-Majmoot.— Crivelli.

caused entirely by the natural crystals of the cast steel out of which they were forged.

The celebrated Polish traveller [illegible]t Rzwruzchi, found an Arabic MS., which [illegible]l that the Turks improved their blades by [illegible]ing them while red-hot with diamond and [illegible] dust, and beating them with a mallet; [illegible]ere the fact or if any advantage could [illegible]ed from such an operation, it could onl[illegible]t they paid dearly for their ignoranc[illegible] employing diamond dust instead of carbo[illegible]uby instead of alumina or silica.

Having fully expressed my opinion on the subject of Damascus sword-blades, I will describe the final method adopted by Signor Crivelli, omitting all his previous experiments to discover the true cause of the patte[illegible], which he appears to have considered purel[illegible]echanical, and therefore failed, however successful he may have been in producing blades of excellent quality.

He first prepares a quantity of the finest cast steel, 1 inch wide and $\frac{1}{10}$th of an inch in thickness, also a quantity of the toughest and best iron wire $\frac{1}{10}$th of an inch in diameter. The steel is cut into lengths of about 18 inches, each of which is bound round with the iron wire in a spiral direction at intervals of $\frac{2}{10}$ths of an inch, and then each plate, or strip of steel, thus bound, is made red-hot, and hammered on

a smooth anvil with a broad-faced hammer, causing the iron wire to indent itself into the steel, and [illegible] to the latter a waving direction also [illegible] the spiral lines of wire are not opposed [illegible] other on the opposite sides of the thin [illegible]ate, it of course bends between them. [illegible]lates, thus prepared, are cut into three [illegible] each, making forty-eight pieces, which are [illegible]ne upon the other, so that the iron wire of [illegible] plate shall fall into the spaces between th[illegible] of each adjoining plate, and the whole [illegible] firmly bound together, and welded. In this process of welding, however, great care is required, and a very peculiar arrangement produced, for the plates are not drawn out in the direction of their length, but hammered in every direction, and finally drawn out into a long bar, in which the ends of the steel plates become the sides of the bar, and the iron wires, which in the first process crossed the plates obliquely, are elongated to fine threads in the direction of the length of the bar, and do not cross its edges at all. This bar is intended to form one sword-blade; previous to which, however, it is cut into three or four pieces, and again packed together and welded, in order to increase the number of laminæ to any required extent: being drawn out again into a bar about half the length of the intended blade, half the

width, and of sufficient thickness, it is ready to receive a further operation, in order to produce a fine pattern on the blade; as [illegible]owever, as the toughness and good quality [illegible]oncerned, there is no occasion to proceed [illegible]

This complex bar is now co[illegible]d of 144 or 192 laminæ or plates, each pla[illegible]nd with fine wires extending lengthways fr[illegible]e end to the other, and curiously interwo[illegible] but to increase the beauty, he files thro[illegible]ne-third the thickness of the bar obliqu[illegible]es with a round file, about half an inch distance from each other; and in the intermediate spaces he does the same on the other side, thus cutting through two-thirds of the bar, and exposing on each side the ends of as many laminæ as are included within that thickness. The bar is then made red-hot, and hammered [illegible]t on an anvil until all these cuts are brought up level to the surface; when the blade is completed by forging it into the desired shape, and then ground, tempered, and polished as usual. The loss of material by these operations was about 70 per cent. I have had many experimental specimens made, and when the pattern is brought out, they are extremely beautiful. In extending this operation I found that a very elegant effect was produced by drilling holes at intermediate and equal distances, one-third through the bar on

each side, with a very wide right-angled drill, instead of the oblique grooves. The pattern I produced by this means consisted of a series of rosettes, or concentric circles, on a ground-work of delicate waving lines. The arrangement of pattern may be varied to infinity, but it is more beautiful the more full. Crivelli mentions that his blades were submitted to the following tests, which are considered equal to any thing ever done. At one blow they cut through thirty folds of felt one inch thick, rolled up, soaked in water, and suspended; also through from six to eight tallow candles of nine to the pound, hung on a line at a short distance from each other: this he considers the most extraordinary. They also severed a cylinder of iron two-tenths of an inch diameter, without injury to the edge. I have endeavoured to procure some of his blades from Austria, but since his death, they do not appear to be manufactured.

Such blades could be made in England at a moderate price, if there were any great demand for them.

The present method of manufacturing sword-blades of the best quality in England is very simple. The steel is made at Sheffield, and sent to the sword cutlers in Birmingham in lengths sufficient to form two blades; the best cast steel is employed; each end is then drawn out by

forging to about half the thickness of the bar, leaving a few inches in the centre the original size, each end in its turn servi[illegible] handle to hold it by while forging the ot[illegible] it is afterwards notched and broken in t[illegible]he centre, and the *tang*, which is of iron [illegible]elded on to the thick end, by splitting op[illegible]e end of the *tang*, or that part which ente[illegible] handle, and the forging of the blade is [illegible]pleted to the desired pattern; after which [illegible]harac ed by passing it backwards and f[illegible]s through a large hollow forge fire until o[illegible]ght red heat, when it is instantly plunged into a tub of water by a cutting movement, edge foremost, which is directly changed to a perpendicular one. The blade in this state is quite brittle, and often very much set or cast sideways: it is again passed through the fire until a certain colour or appearance comes on the blade, known only by long experience, and it is set as straight as possible, by the eye, in a fork fixed on the anvil, and laid aside to be ground and polished, which operations require no description. The ornamenting of the blade is performed in various ways:—first by *embossing*, as it is called; the design is drawn on the polished blade with a composition of vermilion and turpentine, or *stopping*: the fine lines intended to represent shading, or engraving, are scratched in with a needle; all

those parts intended to remain bright being covered with *stopping*. The blade is then washed over those parts with diluted nitric acid, which, in a few minutes, removes the bright polished surface; when the whole is washed off with water and the stopping removed, the pattern drawn is perfectly bright and the ground a dead white. If engraving be desired, the design is faintly scratched on, and then carefully gone over with a fine point dipped in a solution of sulphate of copper. The copper is immediately precipitated, in its metallic state, on the bright surface of the steel. An amalgam of gold being prepared by dropping fine gold into mercury while hot, a portion of this is put into a piece of crape and rubbed over those parts where the copper has been precipitated; it adheres to the copper, leaving it of a very fine colour. The blade is then blued over a charcoal fire, which effects two purposes at the same time; for the heat, necessary to blue the steel, drives off the mercury and leaves the gold only on the surface of the copper, as the amalgam will not adhere to the steel at all. It does not, however, assume the appearance of gold until it has been polished up with putty powder and burnished. This operation finishes the ornamental part, unless an admixture of dead white be required on the blue ground, in which case the design is traced on

the blue with a camel's hair brush and very dilute muriatic acid, which instantly removes it, and the blade is then washed[illegible] combined effect of blue, gold, dead white, a[illegible]ished steel produces a very pleasing and [illegible]l appearance, if skilfully done, and is t[illegible]y ornament put on English blades.

Oriental blades are generall[illegible]amented with gold only, which is raised on [illegible]urface. The blade being first *hatched*, or cu[illegible]ss with sharp and deep lines, the pattern i[illegible] with a wire or needle: all the tools are of [illegible]mplest kind; a punch, or a nail and a hammer, being all that is required. The gold is drawn into fine wire and wound on a bobbin: the native workman commences by taking on[illegible]e gold wire, which is very soft, and f[illegible]ng it to the roughened surface by a few [illegible]ows with his hammer and punch; he rapidly follows out the pattern, and bends the wire backwards and forwards as often as may be required to give additional thickness to the lines, either to form flowers or characters, as may be required, hammering it into the surface all the time, until completed. When polished off, the gold stands above the surface and is very durable.

PART VIII.

ON SOME PECULIARITIES OF IRON.

IRON[1] has been applied to numerous useful purposes, by every civilised nation, for thousands of years; but never has it been so extensively employed as in the present period. We have iron roads and iron carriages; the "wooden walls of old England" will probably be made of iron in another century; numerous steam-boats are already constructed of that material; the cushions of our chairs are stuffed with iron in place of horsehair, and not only our bedsteads but even our feather beds (to use an Hibernicism) are made of iron.

These are, however, merely mechanical applications of this important metal; but when we are told of living animals whose bodies are composed almost wholly of iron encased in flint, and that these animals feed on plants, have the power

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[1] Every one interested in iron should read Mr. Mushet's "Papers on Iron and Steel," just published, as they contain more valuable practical information than has ever before been given on that, or perhaps on any other one subject; the whole being the result of the most unwearied perseverance and continual experiments for half a century.

of motion, and can live in muriatic acid, it may at first excite a smile of incredulity; nevertheless Professor Ehrenberg has d[illegible]ed that the bog-iron ore, from which the [illegible]iful Berlin castings are made, originates fr[illegible]animalcule that once had life, the whole [illegible] being composed of the bodies of myriad[illegible]ese animals; and that the Tripoli or polis[illegible] powder so extensively used in the arts, an[illegible] Berlin to form the casting-moulds in the ir[illegible]undries, is entirely composed of the shel[illegible]milar animalculæ, capable of bearing a[illegible]heat without destroying their outer coating or shell. What is still more satisfactory and more extraordinary, these animalculæ do not form an extinct or doubtful species, but actually [illegible]oundance in the waters and ditches [illegible]erlin; and not only abroad, but so near h[illegible]e as to have been recently met with at Hampstead and Highgate. These are facts calculated not only to astonish, but to establish our extreme ignorance of the laws and operations of nature; and having been demonstrated beyond the possibility of doubt, it is in the power of every one to satisfy himself of the truth of this statement.[1] Professor Ehren-

[1] Vide paper read by Professor Ehrenberg at the Royal Academy of Sciences at Berlin, July 7, 1836, and "Scientific Memoirs," vol. i. part 3.

berg observes, "These living animals are always yellow: in dying they rise to the surface of a grayish-green colour (protoxide of iron), and in sinking to the bottom they again take the yellow colour. Two hundred and eight species of these fossil infusoria have been discovered in various stones, fourteen of which are precisely similar to existing fresh-water infusoria, and five similar to existing marine animals; the other nine are either extinct or not yet discovered. The great mass of the siliceous forms of these animal forms are beautifully preserved, and their characters can be even more distinctly traced in the fossil than in the living ones. The great sharpness and clearness of the outlines of all the siliceous shields appears to have been produced by an extraordinary red heat which has evaporated all organic, particularly vegetable carbon, for the animals then lived, as at the present day, on plants. These animals which are so useful after death, and form entire rocks, have at present a more special interest in their individuality. The annual quantity consumed of these infusoria as tripoli, for casting moulds, polishing, and a variety of purposes, may be estimated at fifty or sixty cwt., in Berlin and the environs. The size of a single one of these infusoria which forms the polishing slate or tripoli amounts on an average to $\frac{1}{288}$ of

a line: the globules in the blood of a frog are about twice the size: about 23 millions of these animals would be contain[illegible] a cubic line, therefore a cubic inch would [illegible] in 41,000 millions, which I found to wei[illegible] grains, or 187 millions go to one grai[illegible]e siliceous shield of each animalcule the[illegible] weighs $\frac{1}{187}$ millionth part of a grain." [illegible] Faraday has shown that iron will remain fo[illegible]nths in *strong* nitric acid, without the sligh[illegible] action taking place, although in diluted o[illegible]er acid it is instantly attacked with viole[illegible] has proved that when chemical action ceases, electrical action ceases also, and *vice versâ*; and has also shown that platinum and carbon act as protectors to iron under such ci[illegible]es.[1] These curious facts sufficiently [illegible] the importance of a subject which appear[illegible]therto to have eluded the grasp of every philosopher. Every artisan who is in the habit of working this metal imagines he understands its properties perfectly, and

[1] A piece of iron raised to a white heat and plunged into a solution of potash (liquor potassæ) became covered with a silvery coating, which did not alter by exposure to air. This must have been potassium which was protected by the iron from oxidation. The experiment did not always succeed, and is merely noticed to draw the attention of chemists to this singular appearance.

so he does as far as regards the mere adaptation of it to his own immediate purposes; but to the chemist and philosopher it presents so many anomalies. [illegible] at the present moment occupies the attention of the scientific men of every country, as they have hitherto been unable to solve [illegible] nical and electrical properties are at [illegible] all preconceived ideas, and it appears to possess some extraordinary relation to other bodies which, whenever it may be satisfactorily explained, will open an extensive field of scientific [illegible], and prepare the way for the most important discoveries. It must therefore be universally acknowledged that iron is the most valuable and most important metal with which we [illegible] ted.

Platinum, gold, [illegible] copper, and most metals in ordinary use, appear when purified, to be nearly the same in quality from whatever part of the world they may be obtained; but iron varies so much, according to the nature of the ore and method of reduction, that hardly two specimens of iron from different countries, or even from different parts of the same kingdom, are alike in those properties which characterise the metals, such as tenacity, ductility, and fusibility. The consideration of these facts having occupied much of my time and caused me to make many experiments, I am inclined to offer some remarks,

which, if not new, may possibly lead those who have more extensive means and opportunities, to pursue the subject with greater advantage than myself. Any attempt to elucidate this interesting subject, even theoretically, must be acceptable, especially if new or forcible facts can be adduced to bear upon the question.

Of all the agents which it has pleased the Creator to employ in the grand system of the universe, there is none which appears to exert so much influence as electricity, taken in its most extended meaning. Gravitation and attraction, the laws by which bodies are *drawn* together, and cohesion, that property by which they are *held* together, have all been referred to electrical causes; and the various branches of science designated Electricity, Galvanism or Voltaism, and Magnetism, which were formerly considered distinct from each other and governed by different laws, have now been demonstrated to be merely modifications of that universal electrical action by which we are continually surrounded, and of which every body in nature appears to partake, but which action is only rendered evident to our senses when the equilibrium is destroyed by some exciting cause. Now, iron is a metal well known to exhibit in the most striking manner the phenomena of electricity in that form called magnetism; and it has always

appeared to me, *that the different states of iron and steel depend on electrical causes modified by the action of carbon and oxygen.* In order more clearly to comprehend this subject, I must briefly, and therefore imperfectly, explain the usual method of manufacturing iron in Europe. The ore is first broken up and roasted, in order to drive off the sulphur and other volatile ingredients; it is then mixed with a certain quantity of blast-furnace cinders or limestone, and either mineral or vegetable carbon, and the whole thrown into a furnace heated with coke or charcoal. The carbon combines with the oxygen of the iron, and escapes in the form of carbonic acid gas, while the clay and silica unite with the lime, and form a kind of fluid glass or scoria, which floats on the surface, protecting the iron from the action of the atmosphere, and acting as a flux: the iron sinks to the bottom, from whence, when in perfect fusion, it is allowed to flow into channels or moulds prepared for its reception, and in this state is called *cast iron*, which is iron

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[1] The iron stone, from which almost all the iron made in Britain is manufactured, is an argillaceous carbonate of the protoxide of iron. Calcareous iron ores are not uncommon, and of course require clay instead of lime. The flux should be as fluid as possible, and must always depend on the nature of the ore.

combined with various doses of carbon and probably oxygen, and other impurities constituting several varieties known as No. 1, 2, 3, &c., or, black, grey, white, &c., according to the quantity of carbon absorbed.[1] When broken, the fracture is coarse and granular, depending on the size of the crystals, and in this state I conceive the crystalline arrangement to be greatly influenced by electrical causes. In order to convert cast-iron into malleable or wrought iron, the carbon and oxygen must be driven off, which is now effected by a process called *puddling* invented about 50 years ago by Cort: this operation consists in exposing the iron to a high temperature in a reverberatory furnace, the flame of which plays upon the metal, which the workman keeps stirring it about until it assumes a pasty[2] consistency; but previous to this the whole mass, at a certain temperature, disintegrates, falling to pieces like sand, the particles having lost

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[1] The proportions of carbon in iron and steel, according to Mr. Mushet, are — soft cast steel, $\frac{1}{120}$; common steel, $\frac{1}{100}$; the same harder, $\frac{1}{90}$; the same too hard for drawing, $\frac{1}{30}$; No. 3. pig or white cast-iron, $\frac{1}{25}$ (light grey fracture); No. 2. or mottled cast-iron, $\frac{1}{20}$ (good melting pig iron, dark grey fracture); No. 1. black cast-iron, $\frac{1}{15}$ (smooth faced, dark blue fracture); plumbago or carburet of iron, about 10 per cent. of metal. — Vide Papers, 1840, p. 526.

[2] Technically called "*coming into nature.*"

all cohesive or electrical attraction: the flame being urged on, the temperature rises and adhesion again takes place; it is then removed and beaten under a hammer of several tons weight, worked by steam or any other power; this condenses the metal and drives out the impurities; afterwards it is again heated and drawn out into bars either by *rolling* or *rolling*. During the process of *puddling*, the mass heaves and swells, giving out jets of flame, evidently caused by the emission of [illegible] gas. The metal thus prepared is malleable iron; it has lost all its former brittleness, and has no longer the granular structure of cast-iron. It is evident that by continual agitation the particles are prevented from assuming the crystalline or natural arrangement: hammering and elongation convert the crystals into fibres, and the tenacity is increased in proportion to the decrease of granular or crystalline structure. In this operation, art interferes with the laws of nature; and malleable iron thus prepared, is iron deprived of its carbon and oxygen, depending for its qualities on a variety of circumstances, such as a minute alloy with the metallic bases of the earths or with other metals and impurities; the strength of its fibres being influenced by the original size of the crystals of which these fibres are composed, in the same manner as the strength of a rope depends, first,

on the quality of the hemp or flax, and secondly, on the comparative fineness or coarseness of the individual threads of which [illegible] formed. In malleable or pure iron, therefore, the crystalline arrangement is destroyed and a fibrous structure induced: in this state it is incapable of being rendered permanently magnetic or of receiving any increase of hardness by sudden changes from heat to cold, as by making red-hot and plunging into water; but if we simply [illegible]atify bars of iron with charcoal in a close [illegible], and expose them to a proper temperature in a furnace for a given time, the *iron* becomes converted into *steel* by the absorption of a small portion of carbon, and its properties are completely altered; it will now permanently retain [illegible]netism, and will become hard enough to [illegible]tch glass when made red-hot and plunged into cold water; it has also completely changed its appearance on fracture, which could only be effected by the particles being removed far enough asunder by the action of heat, to enable them to arrange themselves according to their natural laws at that temperature, which laws appear to be governed by electrical action.

Steel, however, when first prepared as described, is only suitable for common purposes, and is called *blistered steel*, from its appearance. In order to render it suitable for finer purposes,

the blistered steel is either *fagotted* (*i. e.* packed together) and then welded, to form *German* or *shear steel*; [illegible] is broken into small pieces, fused in a crucible, and poured into cast-iron moulds, in order to convert it into the finest kind called *cast steel*.[1] In the latter process, the particles being in a state of fusion, and having a perfect freedom of motion, are at liberty to arrange themselves according to natural or electric laws modified by carbon only: the fracture [illegible] sumes a fine granular appearance, caused by the smallness and regularity of the crystals. The difference between the European and Oriental methods of conversion, consists in the greater simplicity of the process adopted by [illegible]. The natives of India consider that the different kinds of wood employed in the first reduction of the ore, as well

[1] There is one observation made by Mr. Mushet, at p. 27., namely, "*The fusion of steel destroys its property of being welded.*" It may appear presumption on my part to differ in opinion with such a justly established authority, and I am aware that it is considered impossible by many of the workmen themselves: in Staffordshire, I have with difficulty prevailed on excellent welders to make the attempt, but they have succeeded perfectly, to their own astonishment; and I have so often had the finest kinds of cast steel welded together under my own eye, as well as fine cast steel welded to stub iron, that I know it to be practicable with great care and proper management.

as in the subsequent conversion of the iron into steel, have a decided effect in producing different qualities of iron and steel. The *wootz*, or steel, being allowed to cool in the crucible, the particles have sufficient time to arrange themselves and form crystals: hence arise those beautiful combinations which, when forged into sword-blades, produce the Damascus figure, or "*Jowher*," as I have fully explained in my paper on this subject, published in the Journal of the Royal Asiatic Society in 183[illegible] reprinted in a former part of this volume. [illegible]d steel, however, from whatever source obtained, possesses the property of becoming extremely hard by being heated to a bright cherry red and then plunged into water.

The reason appears to be that by the action of heat the particles arrange themselves according to the temperature, and being suddenly fixed by cooling, are held in a state of tension similar to glass when unannealed, and like it also are extremely brittle; the particles, when cold, being by the sudden change fixed in the same position as they were while red hot. This extreme hardness renders the steel unfit for a variety of purposes: it therefore requires to be tempered, or *taken down*, in order to make it available for cutting instruments of every description and for springs; this operation consists

in again gradually raising the temperature of the steel until it assumes various shades of colour caused by the thickness of the oxide formed on the surface, which should be previously polished; the colours produced in succession are, first, a very pale yellow, which comes on at a temperature of 430° to 450°; a straw colour at 460°; a brownish metallic yellow at 500°; then brown, red, and purple to 580°, when it begins to assume a fine deep blue, like watch springs.[1] If the heat be continued until quite red hot, and the steel be allowed to cool slowly, it will become as soft as it was before it was hardened. This takes place in consequence of the particles endeavouring to regain the position which they occupied previous to hardening. At every increment of heat, additional freedom of motion is communicated to the particles by separating them further asunder, which adapts the steel to the peculiar purposes for which it may be destined; but it does not wholly recover its natural state until rendered as soft as possible, by the gradual process of slow cooling. By what power is this continual motion of the particles effected? I conceive it to be *the power of electrical action*

[1] The exact temperature at which these colours appear, vary in different kinds of steel, therefore cannot be precisely determined.

which varies with every change of temperature; heat merely separating the particles far enough asunder to admit of motion taking place: and there is no doubt, I think, that every change of temperature in the atmosphere produces corresponding changes on the particles of all matter, although insufficient to be evident to our senses.

Theories, however plausible, are of little use, unless they can be applied to some practical advantage; and the object I have long had in view is to test this theory by experiments, which want of time has hitherto prevented. I consider, that when steel is in a state of perfect fusion, it is highly probable that its quality might be materially influenced by causes acted upon by artificial electrical currents, allowing it to cool and become solid while under that influence. Experiment alone can determine whether this opinion be correct or otherwise; and, if correct, whether beneficial or injurious.

The accounts already published and in MS. respecting the methods of preparing iron and steel in India, are sufficient for every purpose of general information; but in order to investigate the subject more closely, I am desirous of obtaining specimens from various provinces of India, arranged in the following order, together with

any local information suggested by circumstances; and I am authorised by the Royal Asiatic Society to state, that they will feel obliged to any gentleman whose leisure and opportunity may enable him to forward specimens and replies to their secretary in London: —

1st. Specimens of the ore as taken from the mine, specifying the locality, and whether washed or roasted before being put into the furnace.

2nd. Portions of the iron as taken from the furnace; a few pounds in weight.

3rd. One or [illegible] crucibles with the iron, wood, and leaves, just as prepared by the native workmen, to be placed in the furnace for conversion into wootz or steel.

4th. One [illegible] crucibles, containing the steel, as taken from the furnace after conversion, without being broken or opened.

5th. Several specimens of the wootz, or steel, made at the same time, just as taken from the crucibles, especially those made nearest to Cutch, and usually in flat cakes, about one inch thick, and three or four inches in diameter. Also, if the natives are aware, or have any means of ascertaining by external appearances, whether the cakes are full of "*jowher*" or figure, so as to produce good Damascus sword-blades.

6th. Description of the native mode of working the identical quality of steel sent as spe-

cimens, with any implements manufactured by them from the same.

7th. Specimens and description of the wood employed for charcoal in the furnaces.

8th. Specimens and description of the wood used in the crucibles, and also of the green leaves employed in the conversion of the iron into steel, with the botanical and native names when known.

Some specimens of wootz, or steel, examined by me, and said to come from Cutch, were full of the "*jowher*," or watering peculiar to Damascus sword-blades, and, when forged out, showed most distinctly the crystalline arrangement.

The foregoing questions were forwarded to India in 1837, at my request, by the secretary of the Royal Asiatic Society, and were put into the hands of J. M. Heath, Esq., then at Madras, as being the most competent person to answer them. That gentleman, however, was much occupied, and on the eve of returning to England; but during his passage home he wrote the very able paper "On Indian Iron and Steel," which was published in the Journal of the Royal Asiatic Society (1839), and more recently reprinted in Mr. Mushet's "Papers on Iron and Steel," (1840). Nothing further can be desired as far as the native methods of working are concerned,

but I am still desirous of obtaining all the specimens in the state set forth in my questions.

I shall proceed to make a few observations on the Indian iron now imported, in large quantities, by the *Indian Iron and Steel Company*, one of the managing directors of which is Mr. Heath (the first projector of the Indian iron works), who has devoted many years to the perfection of this manufacture, which is now carried on in Wales on a large scale, and will, very probably, when properly understood, come into competition with the best Swedish iron.

The Indian iron ores obtained in the Salem district, as well as in many parts of India, are very rich, even in the purest state generally found in nature. These are the magnetic oxide, or *fer oxydule* of Haüy, and have been called protoxides; but this is incorrect, as they consist of about $\frac{2}{3}$ peroxide and $\frac{1}{3}$ protoxide, and contain 72 per cent. of iron, and 28 of oxygen, that is, when divested of the earthy matter; the ore itself consisting of 52 oxide of iron and 48 quartz or silica, in 100 parts. After being pounded between two stones, the ore is separated from the earthy particles (wholly silica), either by washing or by winnowing, and it has been imported in the state of coarse sand from India. The price at which the best kind of

Indian iron can be supplied in England is 22*l.* per ton, manufactured entirely with charcoal; the best Swedish iron being 36*l.* per ton.

A quantity of the Indian ore was mixed with about 22 per cent. of charcoal, and exposed to a white heat in a retort: the oxygen combined with the carbon, and escaped in the form of carbonic acid gas and carbonic oxide, leaving the iron nearly pure, in a blueish spongy mass.[1] About thirty pounds were then fused at a very high temperature, and poured into a cast-iron mould; this ingot was drawn down, under the tilt-hammer, to the proper size for twisting into a gun-barrel, and appeared extremely tough and good, either cold or red-hot; but at the first attempt to unite the [illegible] before the welding heat came on [illegible] iron disintegrated and fell to pieces in the fire, and it was not possible to bring a welding heat upon it.[2] It appears to me that the simple operation of drawing out the iron from its fused state, was insufficient to overcome the natural arrangement

[1] This process was patented in 1839 by Mr. Clay, but was first attempted by Mr. Mushet in 1794, and published by him not long after in the Philosophical Magazine, and reprinted in his "Papers on Iron and Steel."

[2] It will be seen on reference to Mr. Mushet's "Papers," p. 544., that he obtained the same result under similar circumstances.

or crystallisation of the mass, and to convert the crystals into fibres; therefore when heated again, nearly to the point of fusion, the electrical attraction was incapable of holding it together at that particular temperature. The same ore, properly treated in the usual way with charcoal, or compressed peat, then drawn down into small nail rods, cut to pieces, and *balled* in the *balling* furnace, would, I have no doubt, be rendered sufficiently fibrous to answer the purpose required in the former experiment.

That very excellent steel has been prepared from this iron under Mr. Heath's directions, I can testify, having for the last twelve months used no other for the mainsprings of the best locks for fowling-pieces, and for a variety of other purposes, and invariably found it superior to any I could procure. At first, it required peculiar management, and would not stand unless hardened in boiling hot water, but this objection (which, on a large scale, was of importance) has now been overcome, and it may be treated as any other cast steel.

Very capital swords have also been made from the same kind of steel, and I think, with such excellent materials to work upon as the Indian ore, a further acquaintance with its peculiarities is alone requisite to ensure uniformity of result, and to render it of great national importance.

Mr. Solly has a patent for preparing steel-iron from English pig-iron, which has been purchased by a company called "The British Steel-iron Company," and I have found some of this steel of very good quality for tools.

Nickel possesses some remarkable analogies to iron, being, when pure, magnetic, but not capable of retaining magnetism until stratified with charcoal, or *steelified*, when it immediately becomes capable of being rendered permanently magnetic. Carbon in all these cases performs some important office which is not clearly understood, but which evidently alters the arrangement of the particles so as to change their electrical properties in a very striking manner. It is probable that other metals may, at some future period, be made to exhibit the same phenomena, or, in fact, that every metal would do so, if we were enabled to dispose the internal arrangement suitably. These ideas being purely speculative, are of no value; but there are numerous facts more extraordinary, and amongst them may be noticed that of cast-iron becoming red-hot on exposure to air after having been submerged in the ocean for centuries, which will form the subject of the following paper.

PART IX.

ON THE EXTRAORDINARY EFFECT PRODUCED ON CAST-IRON BY THE ACTION OF SEA WATER.

The extraordinary effect produced by the long continued action of salt water on cast-iron has been repeatedly noticed, but Dr. Macculloch appears to have been the first to publish his remarks on these phenomena.

In his "Description of the Western Isles of Scotland,"[1] he mentions some curious facts connected with this subject, but does not there attempt to explain them.

I purpose, in the first place, to mention a few remarkable examples, and then I shall endeavour to explain the cause on philosophical principles.

It appears that many of the vessels forming part of the *Invincible Armada* were sunk off the shore of Mull (one of the western islands of Scotland); amongst them was the "Florida,"

[1] Vol. i. p. 536. 8vo.

deeply buried in the sea: but in 1740, Sir Archibald Grant and Captain Roe, with the assistance of divers, attempted to raise the ship without success; they were however enabled to bring up some of her guns both of brass and iron: the former had the mark of an English founder, "R. & J. Phillips, 1584," with a crown and E. R. The iron guns were deeply corroded, and on scraping them they became so hot they could not be touched, but they lost this property after two or three hours' exposure to the air. There was no difference in the appearance of the substance before and after this sort of spontaneous combustion.

Berzelius, in his *Traité de Chimie*[1], mentions, that when the iron [illegible] vessel which had been sunk about fifty years, near Carlscrona, were raised a few years ago and brought on shore, nearly one-third of them was converted into a grey porous mass resembling plumbago, and that they had hardly been in the air a quarter of an hour, when the water within them began to boil, and was driven off in the form of vapour, and that it was impossible to touch them.

On the former of these occasions it is stated that the inhabitants of Mull, and all who wit-

[1] Tom. iii. p. 273.

nessed this phenomenon, were greatly astonished (as may naturally be supposed), and being themselves unable to solve the mystery, they applied to the surgeon of the ship, as being the most scientific man present: he was, however, as much at a loss to account for such unusual appearances as themselves, but said, that although they had been buried in the sea nearly 200 years, yet, as they went down in the heat of action, he supposed they had not had sufficient time to cool!

The most remarkable instance, as well as the most recent, is that of the recovery of the guns of the "Mary Rose." Rapin, in his History of England[1], relates, that on the 18th of July, 1545, a numerous French fleet, consisting of 150 large and 60 small vessels, commanded by Admiral Annebout, arrived off the Isle of Wight, with intent to attack Portsmouth. The English fleet, consisting of only 60 sail, commanded by Viscount Lister in the "Great Harry," were anchored behind the sand-banks off Portsmouth. The French were unwilling to advance, and the English not choosing to quit their strong position, a distant firing commenced and continued for a few days, when the French admiral, having made

[1] Henry VIII., p. 446. 4to. edit.

a descent on the Isle of Wight and destroyed a few villages, returned without effecting any greater object.

Rapin observes, "This was the greatest effort ever made by the French at sea."

During this engagement the "Mary Rose," commanded by Sir George Carew, was so overpowered with the weight of her ordnance, that she sunk, and the whole of her crew, consisting of nearly 600 men, perished with their commander.

This accident occurred in the reign of Henry VIII. of England and Francis I. of France (1545). On the 16th of June, 1836 (nearly 300 years afterwards), Mr. Dean with his diving apparatus raised [redacted] under brass gun, 11 feet long, at Spithead, on which was the following inscription: —"Henricus VIII. Angliæ, Franciæ, et Hiberniæ Rex, Fidei Defensor Invictissimus, F. F. MDXLII. Arcanus di Arcanis, Cesenen fecit." This gun had a cast-iron shot in it, which, when exposed to the air, became nearly red-hot and fell to pieces. At the same time four brass and three iron guns were raised from the wreck of the "Mary Rose." The iron guns were of the ancient description, formed of iron bars hooped together with iron rings, and they were all loaded; but the guns being made of wrought or malleable iron, they

did not exhibit the same phenomenon as the balls, which were made of cast-iron. Those balls, which by their diameter ought to have weighed 30 lbs., were reduced to 19 lbs. 3 oz. The 8-inch or 70 lb. ones were only 45 lbs., although to external appearance the same as regular shot, until they fell to pieces *red hot* on exposure to the air.

These are facts which can easily be ascertained on application to the proper department in the arsenal at Woolwich; and I have in my possession an iron ring which was taken from one of the [illegible]-iron guns of the "Mary Rose," to which I have before alluded.

It is also an extremely curious fact, that the cast-iron gratings which have been long immersed in [illegible] porter *backs*, or vats, of large London breweries, possess the same property of becoming hot on exposure to the atmosphere when the porter is drawn off, for the purpose of cleaning them.

A more rapid decomposition of the cast-iron takes place when electrical action is produced by the contact of dissimilar metals immersed in salt water. It will, I have no doubt, be remembered, that Sir Humphry Davy some years since proposed a method of protecting the copper sheathing of ships by bolting to them *pigs*, or large pieces of cast-iron, which, being the most easily oxidised of the two metals,

effectually preserved the one at the expense of the other. This discovery promised at first to be of the greatest importance, as it fully answered the expectation of the inventor, by protecting the copper from corrosion; but, as not unfrequently happens, the very success of the experiment, by producing some other effect not anticipated, rendered the discovery of no practical utility whatever.

The iron was speedily destroyed by the electrical action, and in two or three years converted into a substance resembling plumbago, or similar to that produced on cast-iron by the long-continued action of salt water only. But this was not the sole cause of its discontinuance; the process of *Darying* (as it was technically called by sailors) was found so effectually to preserve the copper from corrosion, that shell-fish and animalculæ of various kinds which were before prevented by the oxide of copper from attaching themselves to the bottoms, now fastened with impunity on the clean metallic surface to such an immense extent as greatly to impede the sailing of the vessel. This singular circumstance rendered a discovery which promised to be of the greatest national importance perfectly useless. So great, however, was the confidence inspired by the success of early experiments, that the Admiralty orders were, "*that*

all ships should be protected when docked, and *no dock to be kept empty until the whole were done*." Some hundreds of ships were in consequence *protected*, but all the protectors were removed some years since.

Having read nearly all the Reports to the Admiralty on this subject, I have merely made an abstract of some of the most striking:—

"Sheerness Yard, 17th July, 1825.

"H. M. S. Gloucester.—We beg to state that we find the copper below the water unusually foul with animalculæ and weeds, and partially with small muscles and barnacles. The cast-iron protectors are much corroded, and very foul with weeds. We beg to add, that the "Gloucester" was protected about twelve months ago upon old copper, with the exception of what was shifted on the bows.

"(Signed) O. Lacy.
R. Blake."

"Plymouth Yard, 20th Aug. 1826.

"The *Active* revenue cruiser's protectors, placed on her in August 1824, having been yesterday removed in the dock—reported—the copper much worn, and a little foul with weeds near the protectors; the oxidation and decomposition of the protectors being such as to have

occasioned them to have lost nearly half their original weight.

"(Signed) WM. SHIELD."

"Portsmouth Yard, 31st Mar. 1827.

"The Wellesley.—The copper is green, and thickly covered over almost every sheet, nearly up to the water-line, with small shells and spawn of barnacles: but immediately round each of the protectors the accumulation of large barnacles, oysters, muscles, and other matter, forms a thick and united incrustation, extending about 2 feet round those on the bows and quarters, and about $3\frac{1}{2}$ feet above those on the keel at midships, and about 6 feet forward and aft of them, being united under the keel, &c.

"(Signed) J. NOLLOTH. T. RADCLIFFE.
R. BLAKE. S. GOODRICH."

"H.M.S. Wellesley, Portsmouth Harbour,
5th April, 1827.

A similar report to the preceding, and then follows—"I can state from experience, that the *Vengeur's* bottom, when she went out to South America with Sir Thomas Hardy, was so foul that she was kept under a constant press of sail, and the other ships spared her a great quantity of canvass.

"(Signed) FRED. MAITLAND, Capt."

"Plymouth Yard, 12th May, 1827.

"The Redpole packet.—Protectors removed; copper foul, with weed and barnacles diffused over the whole surface, but more particularly in the vicinity of the protectors. The starboard fore protector entirely gone, but the screws remaining in the bottom. The starboard midship protector on the keel hanging by one screw, it being decomposed round all the other screws; the remaining protectors decomposed to about 1½ inches in thickness.

"(Signed) E. C. CHURCHILL.
J. ATKINS.
SHIELD, Commissioner."

It remains for me now briefly to explain the cause of this phenomenon.

It is well known to chemists that carbonic acid gas forms a small portion of our atmosphere, only 1 part in 100; but this proportion is always found, whether we analyse the air on the summit of a mountain or in the lowest depths of a valley, whether in town or country, Europe or Asia; it may therefore be considered essentially a portion of our atmosphere, the other gases being nitrogen, or azote, 72 parts, and oxygen 27 parts. Water, also, that is exposed to the air always absorbs some portion of car-

bonic acid; and it is this acid which slowly and gradually dissolves iron when immersed in *fresh* water: this can be proved by placing bright iron turnings in a phial of common water; the iron soon rusts, or oxidates; but if the water be deprived of its carbonic acid by the presence of lime, and the phial be hermetically sealed, the iron will remain bright for years.

In salt water, however, there is not only carbonic acid, but several saline substances, which combined produce a remarkable change on cast-iron in consequence of the quantity of carbon it contains. The iron is in the course of time nearly all removed from the mass, although the original form and general appearance remain unaltered; the residue is principally a carbonaceous substance, which defends from any further action a small quantity of iron reduced to an almost atomic state of division.

Now, it is also known to chemists, that some of the metals, when minutely divided, have their affinity for oxygen so highly exalted, that they will take fire spontaneously in the open air; and it is to this minute state of division that the phenomenon of cast-iron guns and shot becoming red-hot on exposure to the air is attributable.

The ordinary process of rusting is, in fact (chemically speaking), merely a species of slow combustion. In some cases, where these phe-

nomena have not appeared until some part of the outer surface has been scraped off, it was in consequence of the external coating of carbon defending the minute particles of iron within from the action of the atmosphere.

This subject may be illustrated experimentally by means of a preparation of lead; although, at present, we are unable to exhibit iron artificially in this extremely minute state of division.

If a glass tube be nearly filled with tartrate of lead, and the tartaric acid be driven off by a red heat, the tube being instantly drawn out to a fine point, and hermetically sealed with a blowpipe, this preparation will remain good for months, or perhaps years. It consists merely of lead, chemically reduced to a finer state of division than can be accomplished by mechanical means, combined with a small portion of carbon from the tartaric acid; and if the end of the tube be broken off and the powder shaken out, it will take fire spontaneously in falling through the air, precisely similar to the cast-iron in the examples before mentioned, and arising from the same cause.

The combustibility of iron and steel is well known in the familiar experiment of their rapid and brilliant ignition in oxygen gas; a slight increase of temperature being all that is required to cause the steel to enter into a vivid combus-

tion. Therefore, iron, although used in numberless instances to protect from fire, and to sustain intense heat without injury, is, under other circumstances, one of the most combustible bodies in nature.

PART X.

ON THE BOOMERANG OF AUSTRALIA.

In a former part of this work I have mentioned the peculiar method of throwing the javelin adopted by the Aborigines of Australia: it may not be out of place, therefore, to notice another offensive weapon employed by these people, who are certainly the most uncivilised in the world. I allude to the *Boomerang*, or magic stick, which has, within a few years, become a toy in this country. So much has been said and written on the subject, that I propose to offer a simple explanation of its singular property of returning, after having been thrown forward, which has procured for it the name of the Magic Stick.

This instrument is a flat curved piece of hard wood, about eighteen inches long, three inches wide in the middle, tapering off towards the extremities, and nearly half an inch thick; the native ones are very roughly finished, and vary in size considerably, which is of no importance: it is used either to bring down birds in their flight, or to arrest the progress of men or animals

until they can be dispatched by other means; but its singular property is that of returning to the thrower, which has often excited the astonishment of travellers, and the incredulity of those who have only heard of it, until it has now become quite familiar. This curious fact has been related in such a manner as to render it much more extraordinary than it really is when correctly stated; for if it touch any object in its flight it will not return, although, by some, it has been supposed capable of killing an animal and then returning to the thrower.

The principles on which it acts merit some investigation; and I think I shall be able to prove that this peculiar property does not depend wholly on its form, although the one adopted may be the most convenient for the purpose. Any thin flat body, whatever may be its form, will exhibit the same phenomenon, provided a rapid rotation round its centre of gravity be communicated at the same time that it is projected forward at a considerable angle of elevation. The natives are of course perfectly ignorant of the principles, and, like all other savages, confine their knowledge to effects.

Many familiar instances of rotation causing bodies to return, after being projected forward, may be adduced: a hoop, for example, will return, if thrown forward with a sudden jerk in-

wards from the upper part of its circumference. A billiard ball, struck with force and dexterity just below its centre may be made to pass from one end of the table to the other and return without having touched the cushion. The blow in this direction gives the ball a rapid rotation towards the striker, and at the same time drives it forward, not rolling, but sliding along the cloth, and revolving in an opposite direction; the moment the friction has overcome the projectile force, the ball rolls back by virtue of the original revolving motion communicated to it by the stroke of the queue.

Another instance less known, I have already mentioned in a former part, namely, that of a bullet discharged from a crooked barrel, being thrown at long distances, in an opposite direction to the curvature.

The *boomerang*, however, is influenced by different causes. To exhibit the phenomenon properly, it must be thrown into the air with great force, at an angle of 50° or 60° of elevation, and by an inward motion of the wrist (difficult to describe and not easy to execute), a rapid spin must be communicated to it, otherwise it will not return. I have repeatedly thrown it forward, upwards of forty yards, and it has returned backwards over my head, and fallen fifteen or sixteen yards behind me. If

pieces of card be cut in various forms, rectangular, oval, circular, and semicircular, all of them will return across a room, more or less, when projected from the fingers at a considerable angle of elevation, with a rapid rotatory motion; and it is immaterial whether the rotation be from right to left, or the contrary; the only effect of the rotation being to keep them nearly in the same plane of air as that in which they were propelled, and thus prevent them from obtaining an horizontal position to which they always incline from the situation of the centre of gravity: thus, if left to themselves, they would present their broad surfaces to the air, and descend nearly in a perpendicular direction as soon as the projectile force ceased to operate, if unaccompanied by rotation; but the rotation, continuing after the projectile force has ceased, causes them to slide down the inclined plane of air up which they were thrown, merely because it is *the line of least resistance;* that is, they cannot descend perpendicularly, because their broad surfaces are opposed to the resistance of the air in that direction, while their edges are inclined to the same angle as that in which they were projected. These are the principles on which the boomerang acts, for if it be thrown forward at a small elevation, or horizontally, the rotation has no tendency to cause its return; it

therefore proceeds forward, cutting the air always in that direction which opposes the least resistance, exactly in the same manner as any other body having a thin edge in one direction, and extent of surface in another: for which reason it often winds round, and performs a variety of curious and amusing gyrations in the air, which depend on the relative degrees of projectile and rotatory force communicated to it, and the currents of air through which it moves: but in these instances, although it may describe a semicircle, or even return within the line in which it was thrown, it never returns to the thrower.

PART XI.

MISCELLANEOUS EXPERIMENTS.

THE following experiments serve to illustrate the capability of metals to resist the force of gunpowder, and may be of some practical utility as well as prove interesting merely as matter of curiosity.

Several attempts have been made to employ gunpowder as a gradual projectile force under command, by igniting it in vessels strong enough to resist its instantaneous explosion, and merely making use of the gases generated in the same manner as high pressure steam, thus reducing the force to about one eighth that of gunpowder fired in the usual way, by losing the great increase of volume occasioned by expansion at a high temperature, independently of numerous other disadvantages. It would, therefore, be only loss of time to discuss the probability of success, or to enter into any description of the mechanical means of effecting this object. That gunpowder can be restrained as well as any other power, provided the vessels are sufficiently strong, will be evident by the following experiments: —

Experiment 1.—A piece about 5 inches long was cut off the breech-end of a common musket barrel; it was screwed at the part cut and another plug fitted, so as to have two plugs, one at each end, leaving an internal space of about 3 inches; a percussion nipple was screwed into the end of one of these plugs: this being arranged, one of the plugs was turned out and 1 drachm of gunpowder introduced; the plug was replaced and the powder fired by putting a copper cap on the nipple and striking it with a hammer: the whole force of the powder escaped at the hole in the nipple: 2, 3, 4, 5, and 6 drachms were successively introduced and fired in the same manner without bursting or injuring the piece of barrel; at last 7 drachms forced out one end in consequence of the screw having been carelessly fitted. This defect being repaired, Mr. Marsh of Woolwich repeatedly fired it with 5 drachms, merely holding it with a towel in his left hand and firing it with a blow of a hammer: 6 drachms of powder is the full service charge for a flint musket, and 4 drachms for a percussion musket; yet this immense pressure can be resisted by a cylinder of iron not more than one quarter of an inch thick, and not iron of the best quality.

Experiment 2.—A good musket barrel had a cylinder of brass 3 inches long turned to fit the muzzle and soldered in, so as to close it air-

tight; the plug, or breech-screw, was removed, and a felt wad was pushed in, with a short piece of wood marked to the exact depth the charge would occupy, to prevent the ball rolling forward. A musket ball was then dropped in, and a cartridge containing 3 drachms of powder was introduced: the breech being screwed in, left the barrel loaded. It was fired by a percussion tube; but there was no report: on removing the breech-screw, the ball was found to be flattened. A repetition of this experiment with 4 drachms produced a similar result, but the ball was rather more flattened. With 5 drachms, the ball was *perfectly round and uninjured*: 6 drachms burst the barrel close under the bayonet stud, the ball escaped through the opening, disfigured, but fell close to the barrel. In these experiments the barrel always *advanced* instead of recoiling as usual.

At first it may appear rather anomalous that the ball should be flattened when fired with three and four drachms of powder, but remain perfectly spherical when the propelling force was greater; but on reflection it will be clearly seen, that with the smaller velocity given to the ball by the lesser charges, the air which was in the fore part of the barrel had time to escape round the ball, and therefore offered, comparatively, less resistance than when the velocity became so

great as to condense the air with such rapidity in front, that it could not escape round the ball before the whole force of the powder had escaped at the touch-hole: the air acted as a cushion, and prevented the ball from striking against the end at all, as in the former instances. The barrel also advanced in the same manner as if a piston had been suddenly forced into it at one end while the other was closed, the elasticity of the condensed air driving it forward.

Experiment 8. Made at Woolwich Arsenal with a Gomer mortar, which is a mortar bored conically, so that the shell when dropped in fits closely all round, instead of being bored cylindrically with a chamber in the centre. The mortar being laid at an angle of 45°, one drachm of powder was put into the bottom, and a 68-pounder iron shot over it; when fired, the ball was projected two feet clear of the mortar. A wooden ball precisely the same diameter, but weighing only 5 lbs., was scarcely moved by the same charge, and with two drachms of powder it was just lifted in the mortar and fell into its place again. Here we find a weight of 68 lbs. thrown to a distance of two feet by the same power which would not lift 5 lbs., and was scarcely moved by double the power.

This proves that the firing of gunpowder un-

der such circumstances is not instantaneous. In the first instance, the small quantity of powder had a large space to fill below the ball, and a heavy weight to move; therefore could not stir it at all until the whole was ignited, when the force was sufficient to throw it forward two feet. In the second case, the first portion of gas that was generated by the ignition of the powder was sufficient to lift the lighter weight, just enough to allow all the force to escape round it before it had time to accumulate.

Experiment 4. A 6-pounder brass gun was struck on the side by an enemy's shot at the battle of Corunna, which considerably indented it. Being loaded at the time with the service charge of two pounds of powder, and the indentation being above the bullet, it was rendered useless, and returned to the arsenal with a statement of the circumstance. This afforded an opportunity of trying the strength of the gun-metal as well as of ascertaining whether the charge, which was perfectly dry, would escape at the vent-hole or drive the ball past the dent. The cannon was rammed full of sand down to the bullet, and fired by a long burning fuze to allow time to get out of danger. The whole force of the powder rushed out at the vent, driving the bullet up to the dent, and expelling a portion of the sand. After allowing time to cool between

each discharge, 3, 4, 5 pounds of powder were successively poured in at the vent. With 6 pounds, the rush of flame from the vent-hole was terrific; but the gun did not burst, nor had the ball moved any further. At length, as the space behind admitted it, 7 pounds of powder were introduced: for a moment the flame rushed out, but in an instant the ball was expelled with prodigious violence, driving the column of sand in a cloud before it, and cutting the piece of metal which projected inwardly clean out of the side, without any further injury to the gun.

Perhaps it would be impossible to illustrate more forcibly the immense strength of materials, or the power of restraining within certain limits the prodigious expansible force of gunpowder.

At page 72. I have mentioned the force with which the flame, or rather gas, issues from the vent-hole of a 32-pounder cannon when loaded in the ordinary way, so as to lift a 24-pounder shot several feet into the air.

Experiment 5. A musket barrel having the plug turned out so as to be open at both ends, with a touch-hole made exactly in the centre, was suspended by cords to a beam, and a ball cartridge placed in the centre and fired: the ball penetrated a deal board half an inch thick, at 21 feet distance.

The experiment was not carried further; but

there is no doubt that by increasing the length constantly in one direction, additional force would be given to the ball; as the sudden expansion of the powder in the tube condenses the air, and forces the particles with such rapidity together that they cannot escape instantaneously at the orifice; they therefore form an elastic breeching, similar to a long spiral spring. In the same manner, and on the same principles, a bag full of gunpowder merely hung on the strongest fortified gate will blow it open; or a barrel of powder placed against a wall will overthrow it, although resisted on the opposite side by the air only, which forms a counteracting wall by the condensation of its particles: this may be illustrated by supposing a violent blow to be given to a mass of loose wool; the fibres being driven suddenly together, would accumulate on each other until they opposed a formidable resistance to any further compression.

Experiment 6. In consequence of an opinion that the recoil of a gun was occasioned by the rush of air into the barrel when the charge left it, and that no recoil took place until the ball was out of the muzzle, it was proposed, in America, to demonstrate this imaginary action, and to prove, experimentally, that there would be no recoil at the moment of ignition. In order to effect this object, a wheel about three feet

diameter was mounted on a fine axis moving very freely, and with as little friction as possible; on the circumference of the wheel a stout barrel was firmly fixed, so that the axis of the bore formed a tangent to the circle. The barrel, when turned uppermost, could then, with care, be placed perfectly horizontal, and freely acting like the beam of a pair of scales, with liberty to revolve. When loaded with ball, and fired by means of a thread of quick match inserted into the touch-hole, the recoil would, of course, drive it round, and cause it to make several rapid revolutions. A paper frame, or target, was fixed at a few yards from the barrel in a direct line and on the same level, and it was found that when fired the ball passed through the target in a perfectly horizontal line, and never above the level of the barrel; which was allowed by all parties to prove, in the most satisfactory manner, that no recoil took place until the ball had quitted the barrel, for the slightest motion of the wheel would have elevated the barrel considerably; and the ball must have been thrown above the horizontal line if any elevation had taken place while it was in the barrel.

I am, however, of opinion, that although the experiment was a very ingenious one, and applicable to other purposes, it by no means established the fact attempted to be proved. I think

there can be no doubt, on the contrary, that the ignition of the powder and the recoil are simultaneous, and that it would be utterly impossible to appreciate or to measure the time required for the ball to travel three feet (the length of the barrel), and consequently that there was not time for the barrel to deviate from its horizontal position before the ball had left it; for if we suppose the velocity of the ball to be 1500 feet in a second, it would just require $\frac{1}{500}$ of a second of time to traverse the whole length of the barrel, barely sufficient to overcome the inertia and set the barrel in motion, although the blow once given caused it to revolve rapidly afterwards. Besides which, I cannot conceive the possibility of a vacuum existing at all in the barrel of a gun when fired. The action is produced by condensation, and not by exhaustion: for example, a cubic inch of gunpowder is instantly converted into 2000 cubic inches of gas, which, pressing equally on all sides, communicates motion to the gun as well as to the ball in exact proportion to their relative weights, and to the resistance offered; so that if both were spheres of the same weight and magnitude, they would be projected equal distance from the point of [illegible] considerations will, I think, [illegible] supposition of a vacuum; [illegible] same contrivance with

advantage, to ascertain the strength of gunpowder according to the number of revolutions, or parts of a revolution, which might be easily regulated, and thus form a very good eprouvette. It also affords a ready means of trying the force of rockets, by affixing one to a wheel thus mounted.

Experiment 7. also originated in America, and certainly is one of the most ingenious methods of ascertaining the relative quickness of ignition of different qualities of gunpowder that I have ever met with.

A gun-barrel mounted on a carriage with wheels, and moving on a perfectly horizontal railway, is placed at right angles to another short railway, at any convenient distance (suppose fifty feet, or yards); on the second railway a light carriage moves freely with any desired velocity, being drawn forward by means of a weight and pulleys: a cord is attached to the front of this carriage, which passes over a pulley at the end of the railroad, and is continued up a fixed pole or staff over another pulley at the top, and the weight is appended. A [illegible] frame covered with paper is fixed p[illegible] riage, so that when it m[illegible] across the direct line of [illegible] a long [illegible]

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